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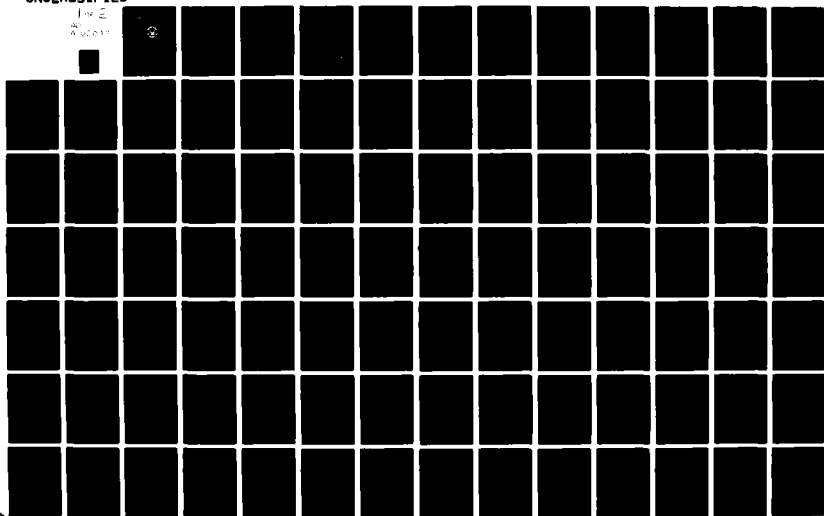
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NAVAL POSTGRADUATE SCHOOL
Monterey, California



THESIS

ECOLOGY AND DISTRIBUTION OF THE
BENTHIC COMMUNITY ON THE MONTEREY BREAKWATER,
MONTEREY, CALIFORNIA

by

Steven J. Busch

March, 1981

Thesis Advisor:

E. C. Haderlie

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Ecology and Distribution of the
Benthic Community on the Monterey Breakwater,
Monterey, California

by

Steven J. Busch
Lieutenant, United States Navy
B.S., U.S. Naval Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

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ABSTRACT

An ecological baseline study was conducted on the Monterey breakwater. Qualitative and quantitative survey of the plants and animals occupying meter square quadrats along a cross-sectional transect covering the breakwater and the adjacent mud bottom out to depths of 13 meters was made. Overall, the differences between the populations of the inner and outer parts of the breakwater appeared minor and primarily involved differences in relative abundance of only a few species. Data from this study establish an ecological baseline for future studies on the Monterey breakwater.

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Most of all, I would like to thank my loving wife Sue and my children for all their support and understanding during all phases of this study.

I. INTRODUCTION

Ecological baseline studies, when properly conceived and executed, can serve as a basis for evaluating possible damage to the marine environment following some natural or man-made accident. To accomplish this, these baseline studies should be conducted in areas where minimal ecological damage has occurred.

Although extensive studies have been done on the wharf pilings in the harbor at Monterey and the kelp beds off Del Monte Beach, there has never been a detailed ecological study of the breakwater.

The purpose of this study was to establish an ecological transect across the Monterey breakwater and to make qualitative and quantitative studies of the plants and animals occupying meter square quadrats along the transect covering the breakwater and the adjacent mud bottom out to depths of 13 m. Data from this study will establish an ecological baseline for future studies on the Monterey breakwater.

The applicability of this study to the Navy lies in the fact that naval officers must have an understanding for the need of properly managing the marine environment. The effects of constructing naval facilities or possible oil spills and their interrelationships with the environment requires the naval officer to draw from many fields of knowledge in interpreting

the effects. To do this, a naval officer must have a working knowledge of how to carry out a basic ecological survey, and prepare and/or interpret environmental impact statements. Also, a naval officer may have to advise on how to properly dispose of wastes and other materials with a minimal impact on the marine environment.

Though the Navy's presence in Monterey harbor and the surrounding waterfront area is limited primarily to port visits from ships, the Navy would have a vested interest in Monterey's marine ecosystem should an unfortunate oil spill occur from one of its ships. This and other studies conducted at the Naval Postgraduate School would serve as reference baselines for any resulting ecological changes.

II. AREA OF STUDY

A. BACKGROUND

1. Monterey Harbor

Monterey harbor is located at the southern end of Monterey Bay approximately 160 km south of San Francisco, California (Figure 1). During the early 1900s, Monterey's waterfront area was a natural roadstead for a growing commercial fishing industry. The continual expansion of the fishing fleet and its shore facilities, over three decades, required construction of a breakwater for protection from storms. In 1931, construction began on a rubble-mound breakwater and this was completed late in 1934.

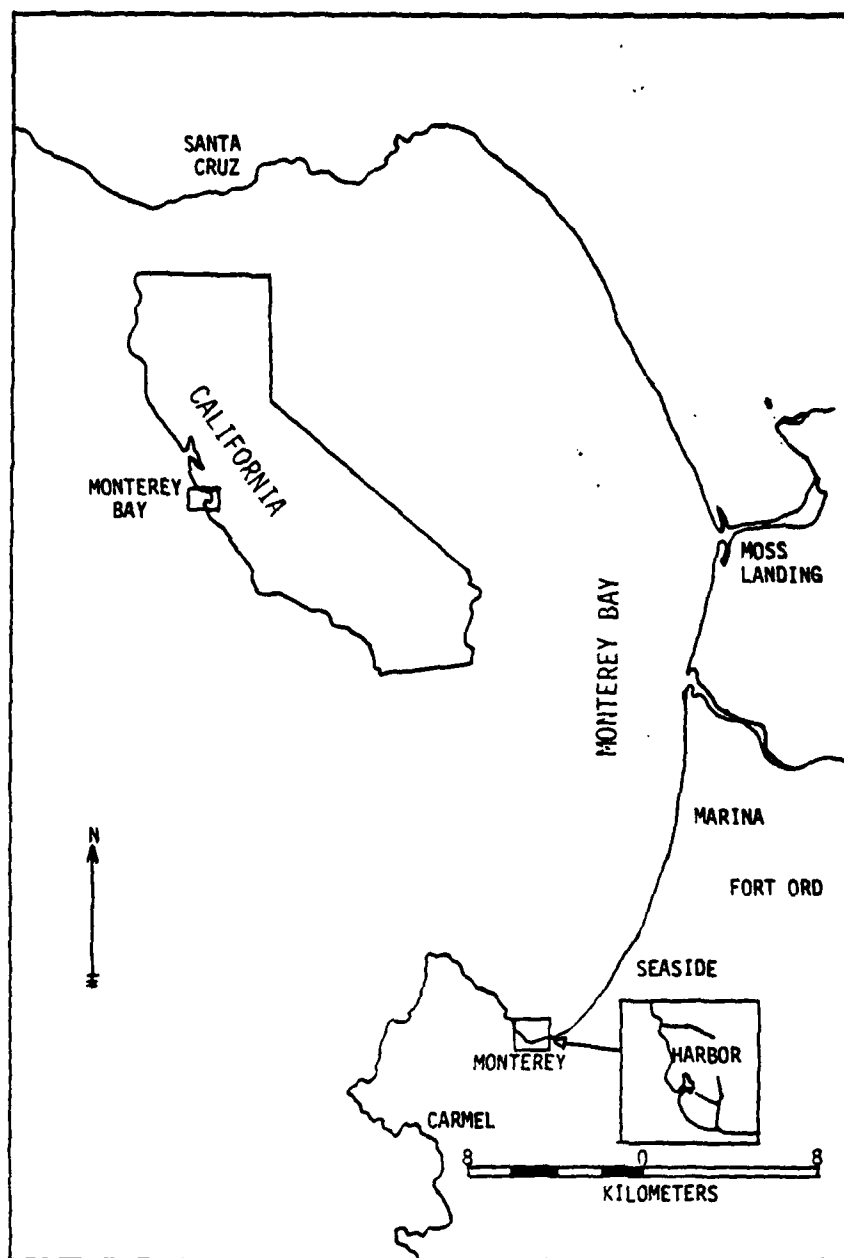


Figure 1. Location of Monterey Harbor

The fishing industry continued to flourish until the decline of the sardine fishery in the early 1950s. Since then, the activities of the harbor have been largely reoriented to recreational boating and tourist attraction features.

2. Breakwater Characteristics

The Monterey breakwater is a typical permeable rubble-mound type preferred for coastal harbors because it is economical, adaptable to any reasonable water depth, suitable on nearly all foundations, and readily repaired. Rubble-mound breakwaters are usually constructed with a heterogeneous assemblage of natural stones of varying shapes and sizes dumped pell-mell or placed in courses. Side slopes and armor stone size are designed to effectively counter the expected wave action. The rubble-mound type is used extensively throughout the United States and almost exclusively on the Pacific Coast.

The first part of the Monterey harbor breakwater was a 393 meter rubble-mound structure begun in 1931 and completed in early 1934. A final 122 meter extension to the breakwater was completed late the same year (Figure 2). Breakwater blueprints (numbers 285 and 728), from the Monterey City Engineer's Office, show the following design parameters (Figure 3): The crest elevation is +3 m above mean lower low water (MLLW) and is 4.6 m in width. The original 393 m has a seaward and harbor side slopes of 33.7° (i.e. rises 1 m in the vertical for every 1.5 m in the horizontal). The 122 m extension has a seaward side slope of 33.7° down to a depth of 4.8 m (MLLW), and 38.6°

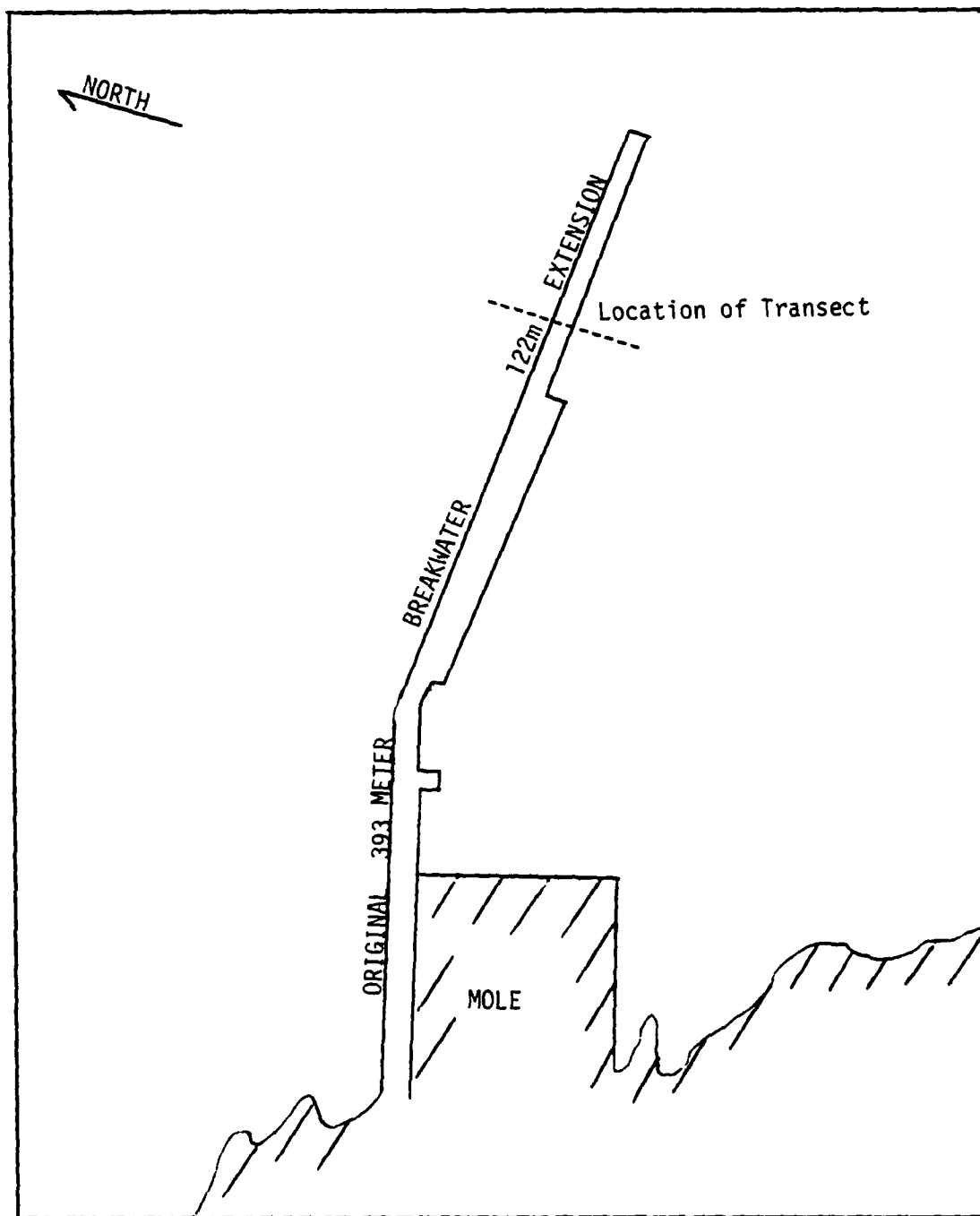


Figure 2. Monterey breakwater showing position of study area

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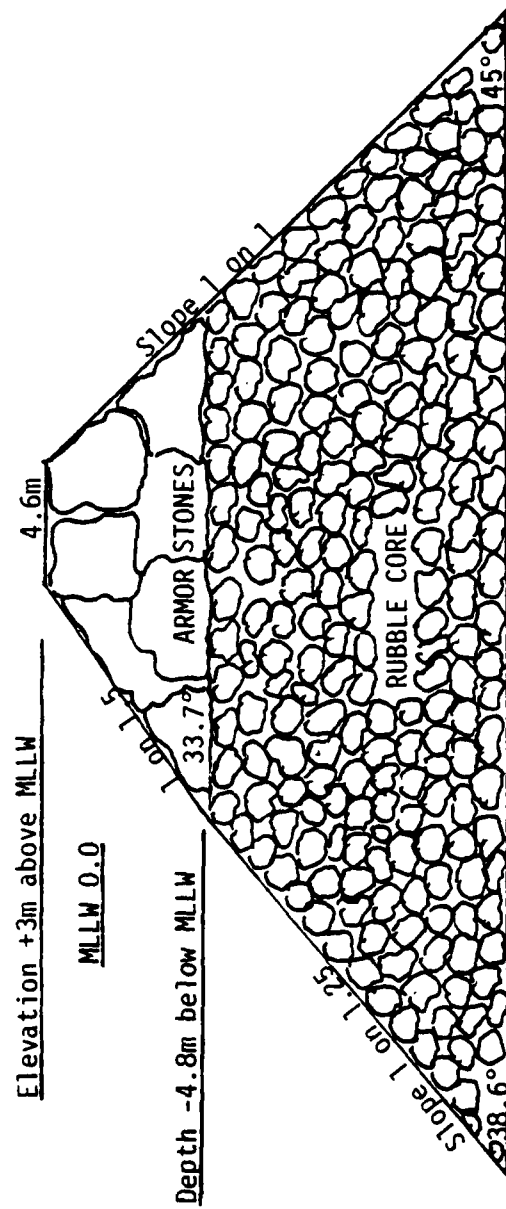


Figure 3. Cross-sectional view of the 122 meter extension of the Monterey breakwater showing design features

(rises 1 m vertically for every 1.25 m horizontally) below that depth. The harbor side slope, for the 122 m extension, is 45° (rises 1 m vertically for every 1 m horizontally). The structural adequacy of the breakwater has been substantiated by the fact that no replacement of stone or other preventive maintenance has been required since it was built.

The granite quarried locally in Monterey for the construction of the breakwater was a Santa Lucia granodiorite of late Cretaceous age, with typical hardness and specific gravities associated with granodiorites. The interior section, or core, consists of granitic quarry waste (rubble), where 50 percent of the rubble weighs more than 227 kg per piece. The exterior "A" stones, or armor stones, placed to attain an interlocking fit, are approximately 9,000 kg per piece for the original 393 m, and 3,000 to 10,000 kg each for the 122 m extension. The original 393 m has a cement cap roadway laid in conjunction with the construction of a wharf and mooring dolphins on the harbor side. Mooring dolphins were also placed along the 122 m extension but were removed during the spring of 1980 due to advance stages of deterioration.

3. Environmental Characteristics

Water motion through the permeable armor stones results primarily from wave surge and tidal fluctuations. Waves overtopping the breakwater were observed when wave heights exceeded 0.5 m and the tide was greater than +1.5 m (MLLW). Wave heights observed during this study were less than 1.0 m. Tides ranged

from a low of approximately -0.5 m (MLLW) to a high of about +2.0 m for the year.

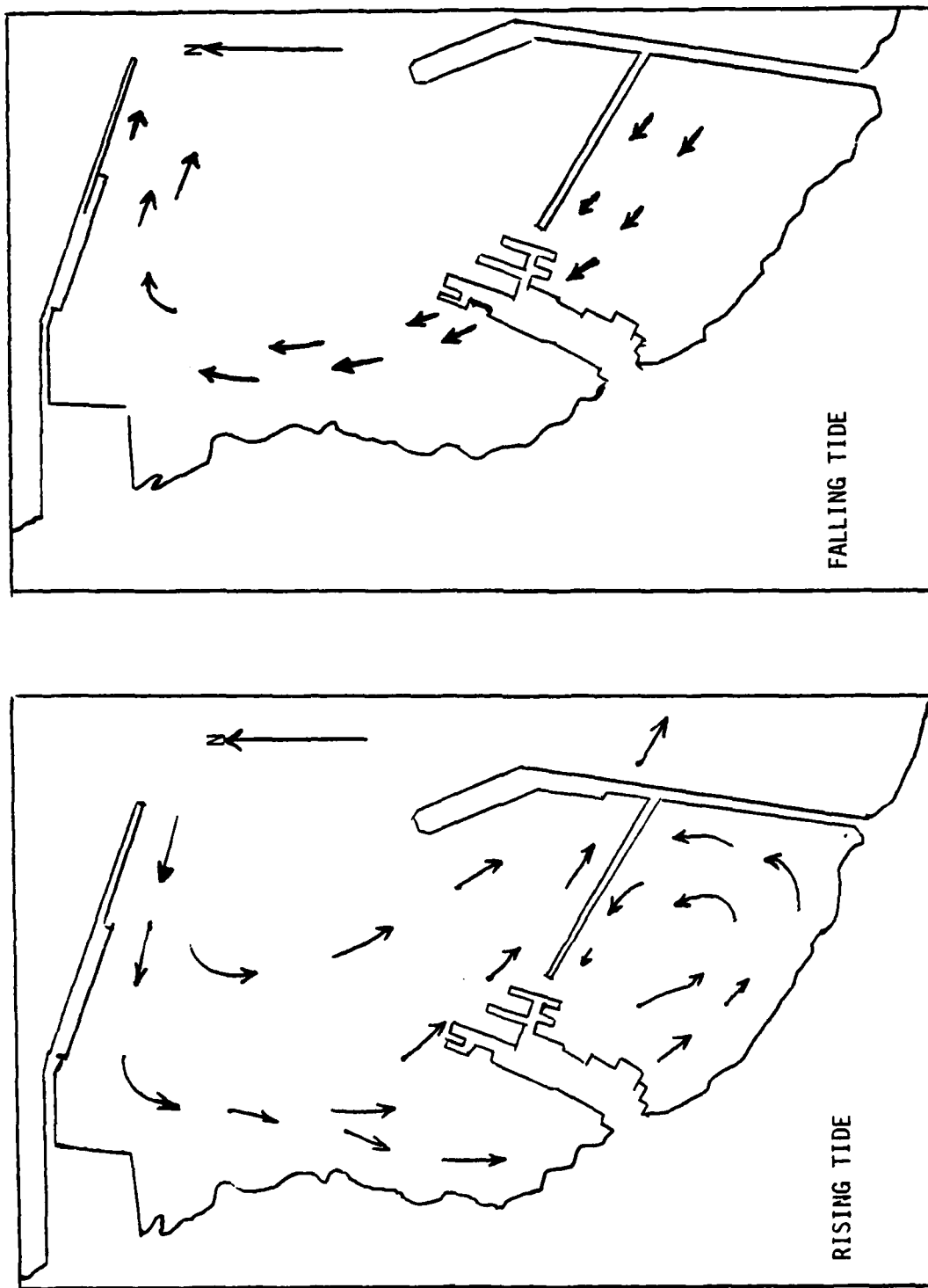
Breidenstein and Thomas (1965) measured currents inside the harbor and found them to be tidally controlled (Figure 4). These currents are predominately weak (2.4 cm/sec) but are of sufficient strength to carry silt-size sediment into the harbor area.

Figure 5a shows the monthly average morning surface temperatures recorded at the tide station at the end of Municipal Wharf No. 2, located 300 m south of the breakwater. Six months of bimonthly water samples for salinity determination were taken at the breakwater from August 1980 through January 1981 (Figure 5b). Salinities were determined in the laboratory using a portable salinometer, Model 6230N by Plessey Corporation.

B. TRANSECT AREA

1. Site Selection

Three criteria were to be satisfied before a particular area was selected for this study. First, the transect area should be situated so as not to disturb unduly the California sea lions residing on the breakwater. Second, the intertidal region through the crest of the breakwater should have sufficient spaces between the armor stones for square meter quadrat sampling. Finally, some sub-tidal caves, found in between the armor stones, should lie along the transect line.



(From Breidenstein & Thomas, 1965)
Figure 4. Tidal current patterns for Monterey harbor

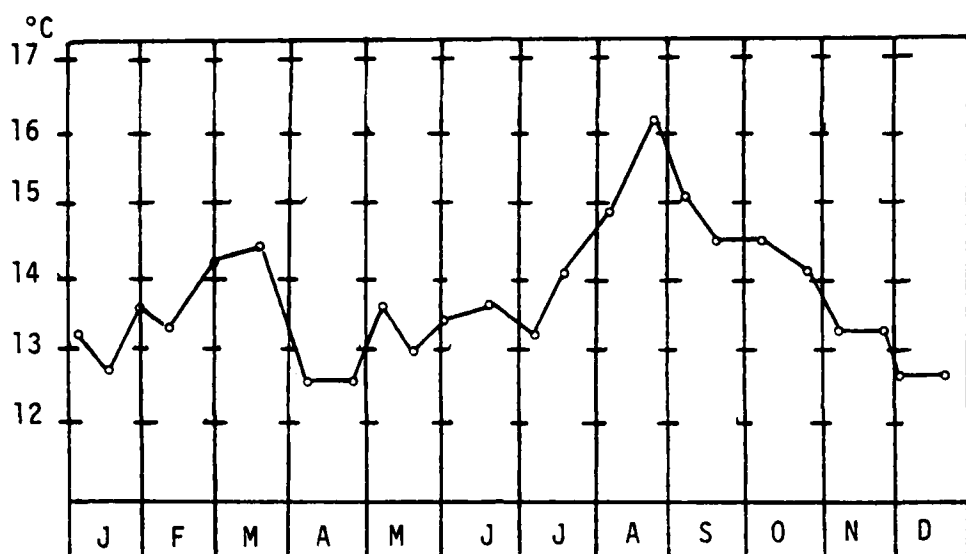


Figure 5a. Biweekly morning surface temperature averages at the tidal station, Municipal Wharf # 2, from 1 January to 31 December, 1980.

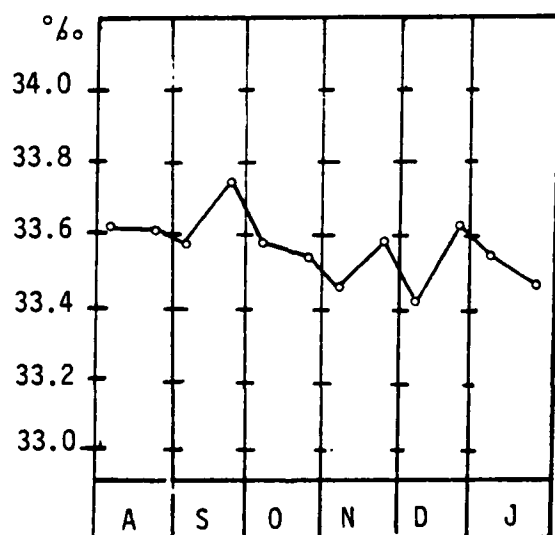


Figure 5b. Bimonthly surface salinity averages at the 122 meter extension from 1 August, 1980 to 15 January, 1981.

The required site was found approximately 25 m eastward of the cement roadway and 5 m from the periphery of the sea lion population. The transect area chosen also had six quadrats located within the crest of the breakwater and three small sub-tidal caves. Further underwater exploration showed that a north-south magnetic heading (5° to the left of the perpendicular on the breakwater) would facilitate underwater marking of the transect and still satisfy the basic criteria.

III. EQUIPMENT AND METHODS

A. GENERAL

Ecology is the study of how organisms interact with the physical and biological parts of their environment. Ecological methods refer to the systematic, orderly procedures for collecting the data for its interpretation. During this study, an ecological transect line was used, instead of random statistical sampling, for two reasons. First, it ensured a complete cross-sectional sampling of the breakwater and the mud bottom out to a depth of 13 m. Second, future repeatable samplings along the identical transect line can be made for direct comparison of data. Sampling was conducted in square meter increments along the transect line using a grid. The grid was nothing more than a moveable, aluminum square meter that established a boundary area (quadrat) for identifying and counting the organisms along the transect line.

A total of 185 dives were made during the period of study using standard scuba equipment. Diving began in February 1980, with the first four dives made to determine the optimum location for the study. The following 13 dives consisted of laying out and measuring the transect line selected. During the following months of March and April, the intertidal quadrats were sampled. This allowed for testing of collection methods and increased the investigator's ability to identify organisms in the field. The next 86 dives, from May to September, involved sampling the 39 sub-tidal quadrats (designated by the letter Q) on the seaward side of the breakwater. The following 72 dives, during October 1980 to mid-January 1981, were devoted to sampling the 33 sub-tidal quadrats (designated by the letter S) along the inside or harbor side of the breakwater. An additional ten dives were devoted to other general observations.

On the average, the study of each quadrat required two dives, with eight quadrats needing three dives to complete the sampling (Table 1). This latter normally occurred when a quadrat was located at interfaces between the armor stones and rubble or the rubble and mud bottom due to the changing biota associated with each substrate. Three dives were also required for the study of quadrats Q10, Q15, S7, and Q21 encompassing three caves and half of a Macrocyrtis pyrifera holdfast, respectively. Bottom time for each dive was a function of depth with dives below 10 m averaging 60 minutes and above 10 m, 90 minutes. Total hours logged underwater was 230.

TABLE I

Number of dives for each quadrat*

Outer Breakwater	Dives	Inner Breakwater	Dives
Q1-Q6	-	S1	-
Q7	2	S2	2
Q8	2	S3	-
Q9	2	S4	-
Q10	3	S5	2
Q11	2	S6	2
Q12	2	S7	3
Q13	2	S8	2
Q14	2	S9	2
Q15	3	S10	2
Q16	3	S11	2
Q17	2	S12	2
Q18	2	S13	2
Q19	3	S14	2
Q20	2	S15	2
Q21	3	S16	3
Q22	2	S17	2
Q23	2	S18	2
Q24	2	S19	2
Q25	2	S20	3
Q26	2	S21	2
Q27	2	S22	2
Q28	2	S23	2
Q29	2	S24	2
Q30	2	S25	2
Q31	2	S26	2
Q32	2	S27	3
Q33	2	S28	2
Q34	3	S29	2
Q35	3	S30	2
Q36	3	S31	2
Q37	2	S32	2
Q38	2	S33	2
Q39	2	S34	2
Q40	2	S35	2
Q41	2	S36	2
Q42	2		
Q43	2		
Q44	2		
Q45	2		
	<u>TOTAL 86</u>		<u>TOTAL 72</u>

*Refer to figures 6 through 9 for quadrat location.

B. EQUIPMENT

In order to maintain the integrity of the populations of organisms found along the transect line, the collection of animals and plants was kept to a bare minimum. Yet some representative samples had to be collected for laboratory identification. The collection of organisms required a wide range of rather simple tools that were readily available. Putty knives, of varying thickness and stiffness, were required for scrapping and prying off attached forms. Small forceps were needed for handling the more delicate organisms and a larger pair for reaching into crevices to pull out crabs and other animals. A hand-held coring apparatus (5 cm inside diameter) was used to collect core samples along the twenty quadrats on the mud. Collected organisms were placed in an assortment of plastic bags or 3.78 liter plastic jars, which could be firmly sealed. All tools, jars and bags then were placed in a large divers' nylon bag that could be clipped onto the diver's weightbelt.

Drawings, notes, and species tabulations were recorded on three 41 by 31 cm bakelite slates, ringed together in notebook fashion. A pencil was inserted into a surgical tube and tied to a ring by a 40 cm cord. On the slates were a listing of the organisms that could be identified in situ, which facilitated the tabulation phase of the sampling. Also, a grid drawn to 1/5 scale on one of the slates was used for drawing a sketch of each quadrat.

Two square aluminum grids were used in the sampling process. The first grid was divided into 100 squares, each 10 cm^2 , by a series of crossing wires. This grid was used only on the armor stones. The second grid had no inner divisions and was used on the rubble and mud portions of the transect. This allowed for stones to be pulled out of the quadrat for sampling, or coring samples to be taken, without any major interference to the remainder of the quadrat.

C. MEASUREMENT METHODS

1. Transect Centerline Position

The transect's centerline position, on the crest of the breakwater, was determined by running a tape measure from Monterey County Disk (No. 301). This disk is located at the end of the cement roadway, directly under the Coast Guard small craft warning tower (Latitude $36^{\circ} 36' 32.141''\text{N}$, Longitude $121^{\circ} 53' 23.998''\text{W}$). One end of the tape was placed on the disk and then the tape measure was walked out to the transect's centerline position and measured. The transect's centerline position was 26.57 m eastward of the disk (refer back to Figure 2). The centerline position has been marked by a red "X" for future reference.

2. Transect Centerline Elevation

The transect's centerline elevation above MLLW was determined by running a double-run third order level using the Ni 2 self-leveling level, made by Zeiss Corporation, and level

rods. The tidal datum used was bench mark 21M (elevation +7.31 m) located at the west corner, right angle curve of Canary Row at the foot of the breakwater. The centerline elevation was determined to be 1.58 m above MLLW.

3. Transect Marking, Measuring, and Mapping

Marking off the transect required having three fixed reference points. One at the centerline position and one fixed reference point at the bottom on each side of the breakwater. The centerline position was conveniently over a fissure on an armor stone, in which, a one meter long two cm diameter rod was driven into the fissure. The bottom references consisted of two 12 kg cement clumps with eyebolts. The clumps were run out on north-south magnetic headings, using a surveyor compass, from the centerline position with a Zodiac boat and lowered down onto the mud with handlines. Next a diver swam a nylon line, marked in one m increments, out on a north-south magnetic heading, using an underwater compass, from the centerline position to a distance of ten m from the bottom edge of the breakwater. The clumps were picked up by the diver and finally positioned by placing the clumps at the end of the line. The nylon line was then pulled taut and tied off at the clumps and rechecked for an accurate north-south magnetic bearing.

Once the bearings were checked, one meter long scrap metal rods were sunk into the rubble, every two meters, along the transect line. Rods were driven into the armor stones whenever a suitable fissure occurred along the transect line. The

transect line was then untied from the clumps and secured between each rod and rechecked again for proper bearings. The whole procedure for the outer breakwater had to be redone for on one occasion divers had completely removed all the rods.

Mapping of the transect line required measuring the dimensions of each rock and recording their depths. Measurements were made using a plastic meter stick that could bend somewhat without breaking. Proceeding down the transect line, measurements were made in one meter increments. All depths were recorded, using a Scubapro helium-filled depth guage, along with the time, and then converted relative to MLLW using the Tide Tables 1980 for West Coast of North and South America. The depths were rechecked on three other occasions, once at a high tide, low tide, and at MLLW. Figures 6 through 9 show cross-sectional profiles of the transect line and relative quadrat locations along the transect line.

D. OBSERVATIONAL METHODS

1. General Quadrat Sampling Techniques and Identification of Organisms

The initial work on each quadrat consisted of describing the quadrat in terms of gross topographical and biological features. During this examination the identity and numbers of all large benthic animals, such as seastars and crabs, were recorded. These animals were then removed and placed in a previously sampled quadrat, to help facilitate the ongoing sampling process. The quadrat was then divided into four 50 cm² areas and the

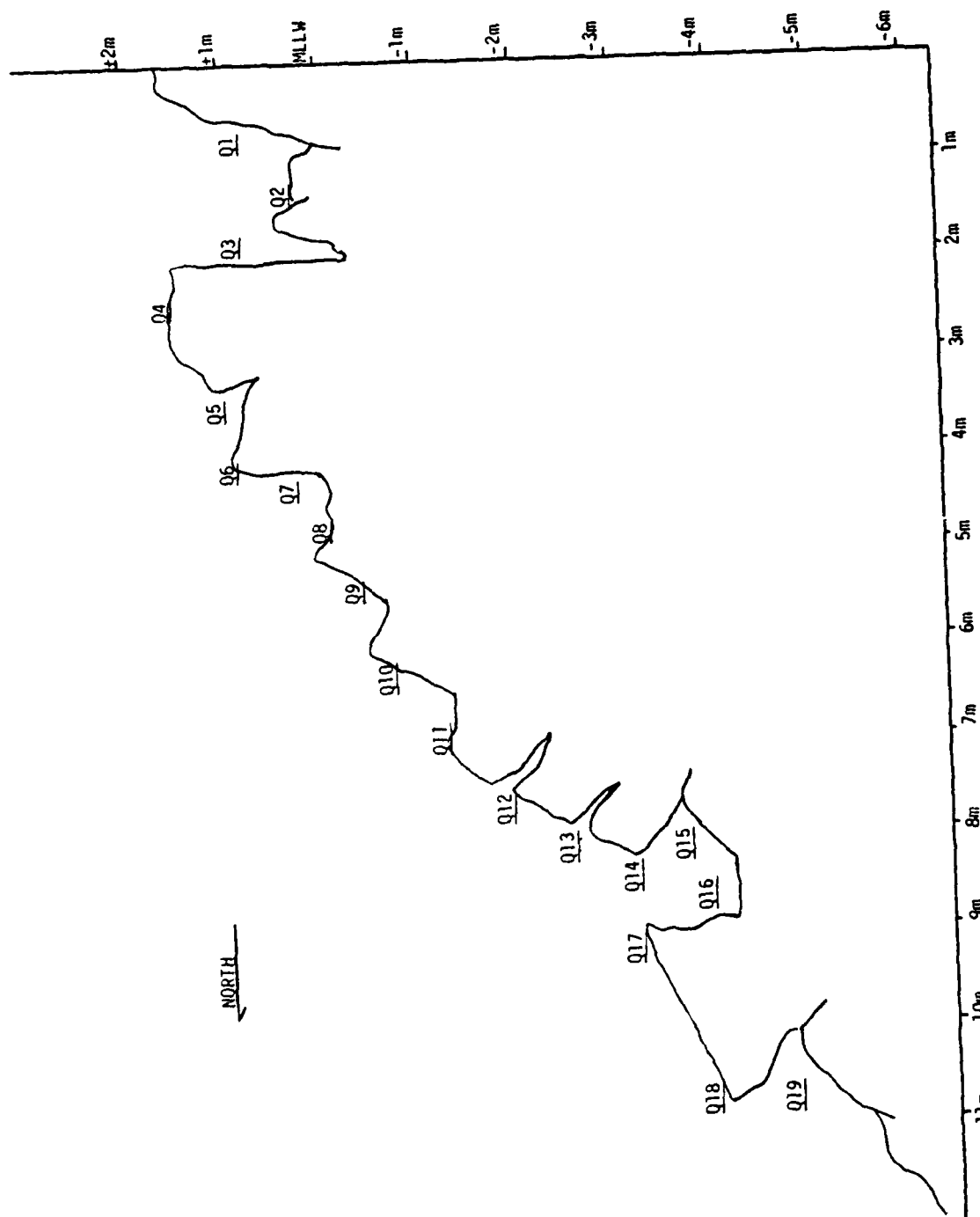


Figure 6. Cross-sectional profile of outer transect, armor stones, with relative positions of quadrats Q1-Q19.

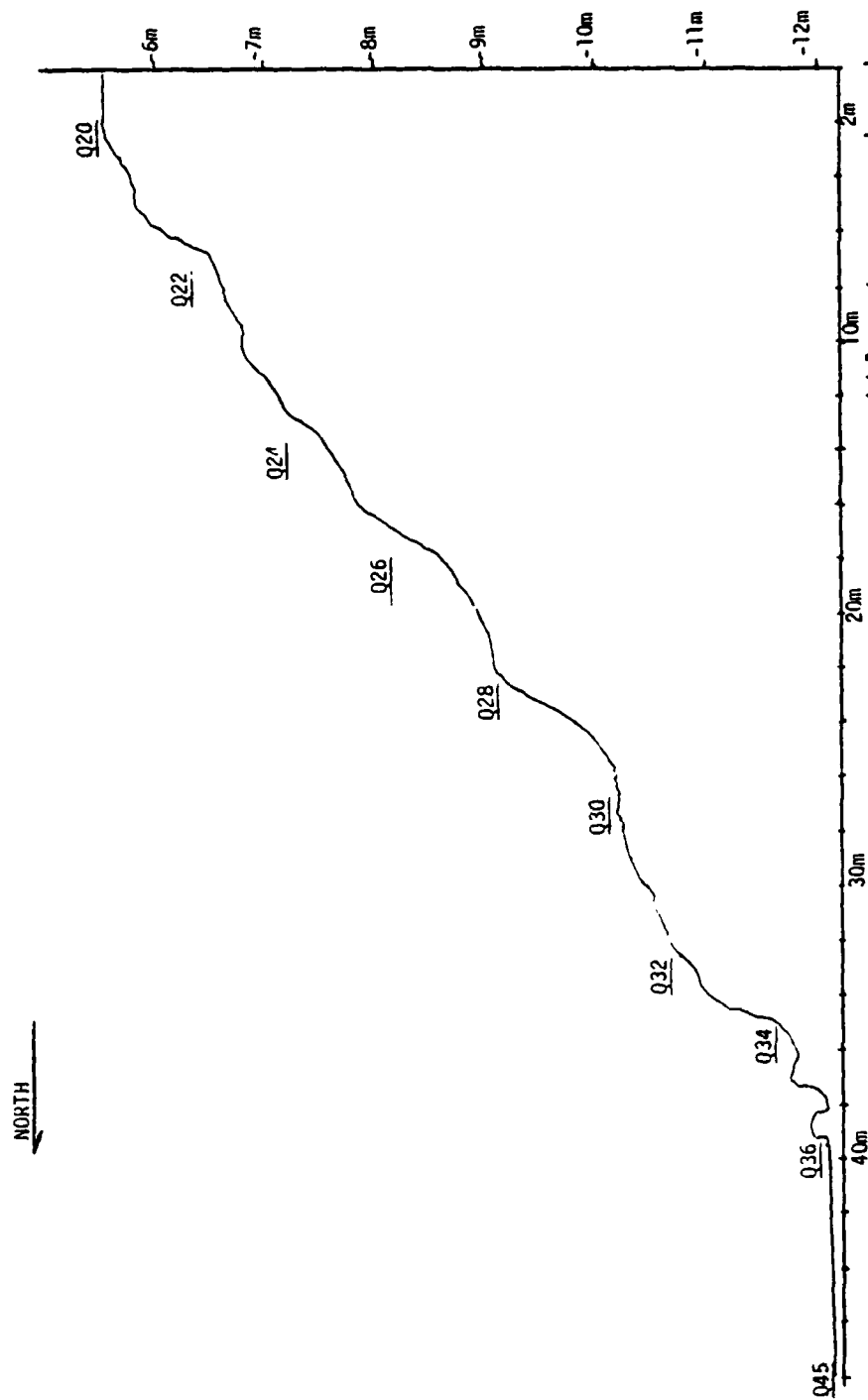


Figure 7. Cross-sectional profile of outer transect, rubble stones and mud, with relative positions of quadrats Q20-Q45.

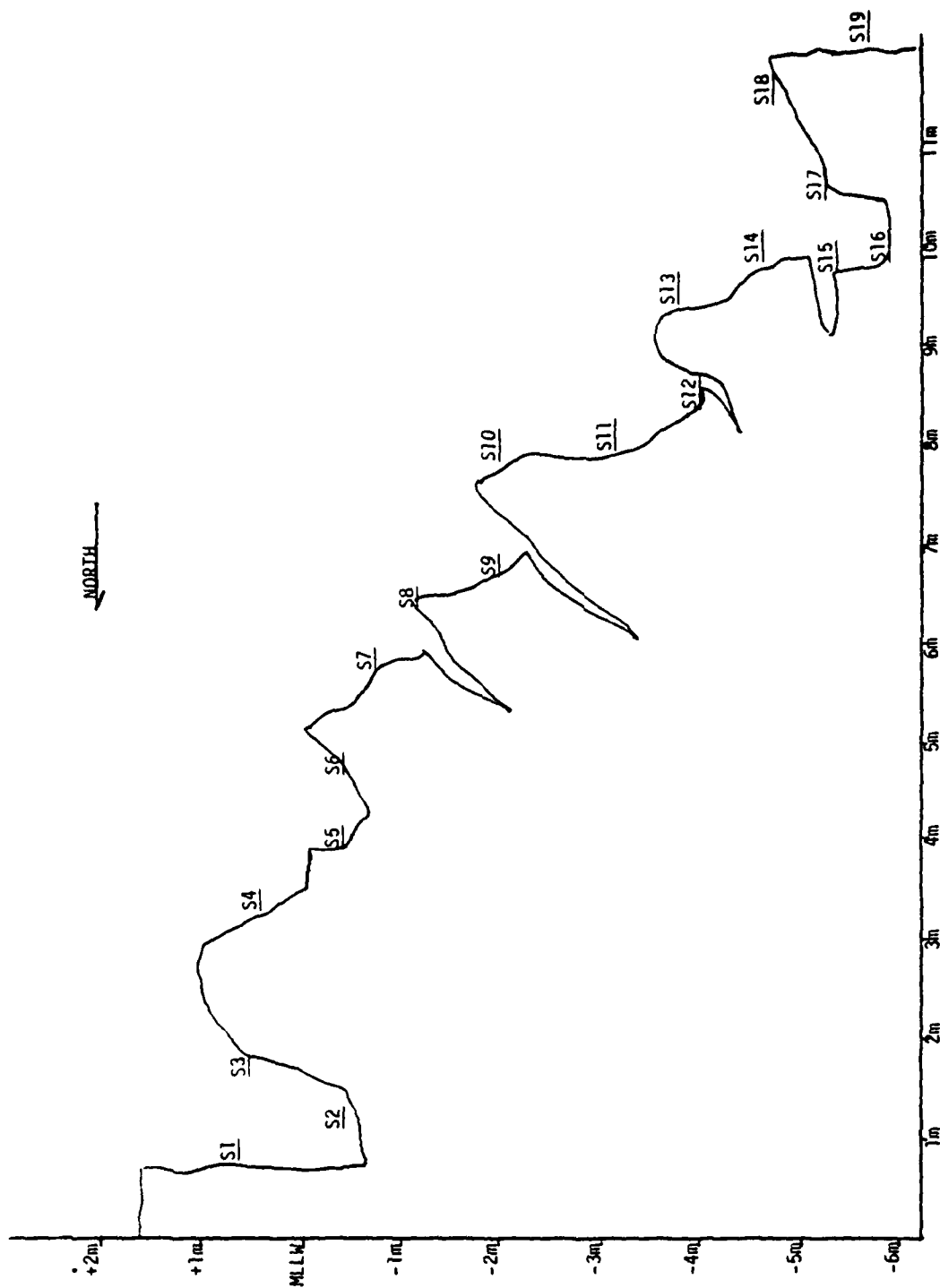


Figure 8. Cross-sectional profile of inner transect, armor stones, with relative positions of quadrats S1-S19.

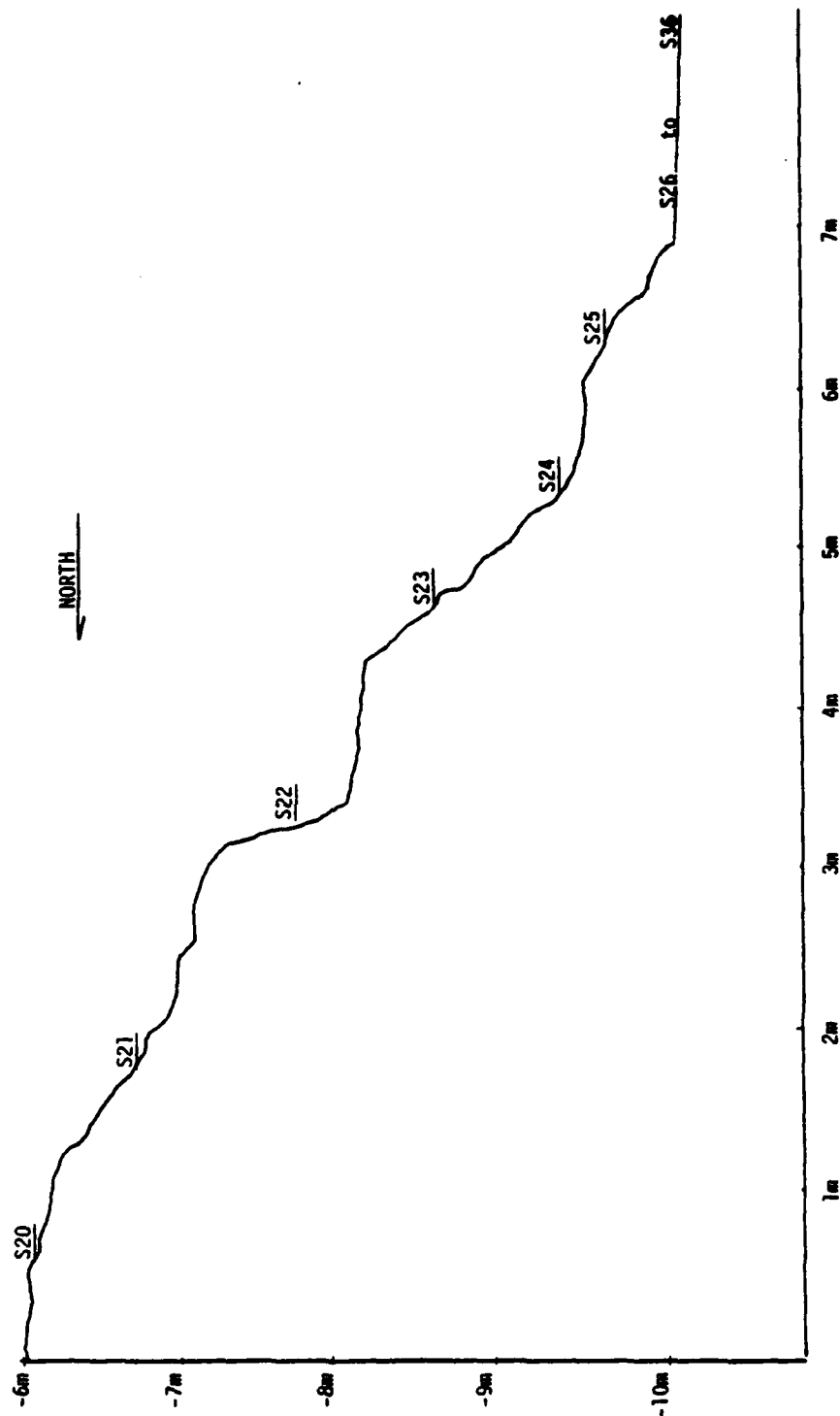


Figure 9. Cross-sectional profile of inner transect, rubble stones and mud, with relative positions of quadrats S20-S36.

algae were identified and tabulated for each inner grid. Immature algae posed the greatest difficulty as they had to be collected and brought back to the laboratory for microscopic examination. Once identification and enumeration of the algae were completed, the four 50 cm² areas were examined again and the animals on the exposed surfaces were identified and tabulated. If new or unknown species were encountered, samples were taken and labelled for laboratory study and their numbers noted. As the investigator gained familiarity with the species present, many organisms could be identified in situ. However, there were many exceptions and these animals all had to be collected for positive identification. Some examples were the sponges, encrusting bryozoans, and immature crabs. Once the exposed surfaces were completely studied, sampling began on the undersides of the rocks or if out on the mud, core samples were taken. Each sampling technique will be addressed later on.

Once any one quadrat study was completed, the grid was placed in the next square meter increment (quadrat) and secured down to prevent any slippage. On the chance that it might be disturbed by a passing diver or heavy bottom surge during the investigator's absence, its position was measured and recorded from prominent bottom features so that it could be reset, quickly. This allowed the diver to begin sampling the new quadrat immediately upon the next dive.

2. Sampling Techniques - Caves

The three small caves encountered were actually under the grids, but required swimming down and around the armor stones

under an imaginary stereoscopic projection of the grid through the armor stones into the caves. The dimensions of the caves did not allow the grid to be placed inside. However, by running lines, from the secured grid, into the caves and using a meter stick a representative grid was laid out in the cave. The same sampling technique, as mentioned earlier, was carried out, but was very slow and cumbersome due to restricted mobility and the use of an underwater light. The dominant organisms were sponges, barnacles and encrusting bryozoans.

3. Sampling Technique - Rubble Stones

Once the sampling on the exposed surfaces was completed, the rocks were turned over, one at a time, and the organisms were identified, counted, and collected if required. The depth into the rubble core that could be excavated was a function of slope and rock size. As the rocks were removed and turned over, a critical point would eventually be reached where rocks from previously sampled quadrats would slide down into the excavation. This would contaminate the tabulation and cause unnecessary damage to the organisms living on these rocks. Sampling excavation was also stopped when rocks too heavy to lift were encountered. The deepest excavation was 83 cm, with the average being 50 cm. Once the sampling was completed, the stones were returned to their original order and position and every attempt was made to reconstruct the area in its original form.

4. Sampling Technique - Mud

The mud quadrats were studied only on days when underwater visibility was excellent and there was little or no bottom surge. Upon reaching the base of the breakwater, and before venturing out onto the mud, the divers' swimfins were removed to reduce the turbulence that stirred up the sediment. After the quadrat was reached and the collecting equipment set up it normally required several minutes of lying motionless on the bottom to allow the disturbed sediment to resettle. Sampling was then carried out, as previously described, but all movements had to be calculated and executed slowly or visibility would be momentarily lost. A hand-held coring apparatus (5 cm inside diameter) was used to collect ten random core samples at each quadrat from the top ten cm of sediment, giving a total sampling area at each quadrat of 0.05 m^2 . Samples were emptied into 3.78 liter plastic jars, sealed, and returned to the laboratory. There they were washed through a screen and the animals were sorted from the sediment and identified.

5. Species Numerical Determinations

Whenever possible, tabulations were done on an individual to individual basis, a slow but accurate method. On several occasions, a single species was found to dominate a quadrat and their numbers required confining the tabulations to one or more 10 cm^2 areas. Then an appropriate factor had to be multiplied to the 10 cm^2 area to obtain a corresponding number for a square meter or some fraction of a square meter. A prime example was

the annelid worms of the family Spiroborbidae. All identification and enumeration of spirorbids was done under the microscope in the laboratory. Four representative rocks, from four different quadrats, were brought back to the laboratory and one 10 cm² grid was secured to each stone. Inside the 10 cm² grid was placed a movable one cm² grid. The rock was placed under the microscope and the spirorbids were identified and tabulated for 100 squares, each one cm². This procedure was repeated for each rock and then the numbers for each species were averaged for each side of the breakwater. Since, the spirorbids on the armor stones could not be brought back to the laboratory, three squares each 10 cm² were tabulated for total spirorbids on each side of the breakwater. The three tabulations were averaged and then multiplied by the percentages found from dividing each species population by the total spirorbid population from the rocks brought back to the laboratory. This gave an estimate of the percentage of each species on the armor stones for a given population count. See Appendix C for a statistical breakdown for each species.

6. Problems and Errors

The original objective of this study was to sample a transect area in square meter increments while doing as little damage as possible to the area. As a result, no attempt was made to scrape off all the organisms and return them to the laboratory for identification and tabulation. By leaving the quadrats relatively undisturbed a baseline was established that

allows for future comparative studies. As a result of these precautions, the enumerations of numbers of individuals of any one species were minimums and were not indicative of their total abundance. Also, organisms were found deep within the rubble core and probably extended downward as far as their oxygen and food requirements would allow. Though every attempt was made to collect previously unrecorded specimens, some of the more mobile animals eluded capture. Animals living in deep crevices had to be identified and counted from a distance using a light. Many of the very small macroscopic animals, such as amphipods, were too numerous and too difficult to capture and no attempt was made to sample them.

On some occasions, errors might have resulted from fatigue and cold setting in after the third or fourth dive on a day. The precise location in the quadrat was sometimes lost when the diver was distracted by overly friendly sea lions. It was also impossible to correct for animals migrating between quadrats from one day to the next. At the start of this study, all these possible errors were realized and whenever possible were minimized.

IV. PRESENTATION OF RESULTS

A. GENERAL

The results of this study are presented in four parts. Appendix A and B are Tables of Species, for the outer and inner breakwater, respectively, with species abundance at each quadrat

interval of sampling. Appendix C is a Species List with comments on some selected organisms. Appendix D is a List of Fishes with general comments on their distribution.

In the Table of Species, the specific animals and plants are listed by phyla. Numbers in parentheses next to the phylum name represent the number of species found and assigned to that phylum. The column "Lg. Dim" tabulates the largest approximate dimension recorded for each species. Sizes for the colonial forms represent the largest dimension of the colony.

Species tabulations are given primarily in numerical notation, with the exceptions of the quantitative symbols "A" and "P" and the percentage of coverage per m^2 for the coralline algae Lithothamnium. These symbols are explained in Table IV at the end of Appendix B.

The Species List (Appendix C) is also arranged by phylum with further subdivisions (i.e. classes, families, orders) given for clarity. The invertebrate keys found in Smith and Carlton (1975) were used in making most of the identifications and in assigning species names. Organisms identified using other sources have such sources indicated after the comments. Comments are made on selected species, and these refer to their distribution, occurrence, new range extensions, or difficulties in identification.

B. OUTER TRANSECT

A progression along the transect line, northward, down and through the intertidal quadrats (Q1-Q7) showed these quadrats to be characterized by low species diversity (approximately 40 species) and high densities, ranging up to 9,154 individuals per m². The most abundant organisms, the barnacles, made up 80 percent of the total population.

The highest sub-tidal quadrat (Q8) showed a significantly higher diversity (about 65 species) while maintaining upwards of 6,000 animals per square meter. Sub-tidal quadrats (Q9-Q15) showed a continually increasing diversity (averaging 77 species) with densities approximating 4,000 individuals, this number being biased somewhat by the large colonies of the tubed annelid worm Dodecaceria fewkesi (55 percent of the total population). Red algae, especially the corallines, became the dominant plants throughout these quadrats. Here, the brown algae were conspicuously absent, which was probably due to the unfavorable conditions caused by excessive wave surge and turbulence.

Quadrat sixteen (Q16) was the first quadrat encountered which contained rubble stone. It was unique, as it was protected by armor stones on three sides. Also, it harbored five of 22 species that were only found once on the entire outer transect. Several of the organisms found are rare or uncommon in this region (i.e. Pseudopotamilla intermedia, Paraxanthias taylori, and Searlesia dira).

The deepest armor stone (in quadrats Q17-Q18) was marked most conspicuously by scattered red algae, primarily Rhodymenia pacifica and, to a lesser extent Gigartina exasperata. Invertebrates were noticeably scarce, represented by several species of encrusting bryozoans and small crabs. The scarcity of animals was probably due to the flat profile of the armor stone, which afforded no depressions or cavities for animals to reside in.

Though quadrat Q19 covered the undersides of the above armor stone, its lower profile was buried under rubble stones and can be treated along with the rubble quadrats (Q20-Q35). The most striking feature in the distribution of the animals in the rubble quadrats was the pronounced increase in their diversity, averaging 85 species per quadrat. The abundance and the diversity of the organisms was even more pronounced from quadrats Q20 to Q25. Here, tunicates were numerous, along with the bryozoans. Sponges were well represented with 13 of 18 identified species found within this region. The chiton, Placiphorella velata, was more abundant at this locality than at any other locality along the transect. Also, at these quadrats, the red alga Rhodymenia pacifica became dominant and remained so down the transect. It was here also that the brown alga Macrocystis pyrifera was found and occurs at this depth throughout the length of the outer breakwater.

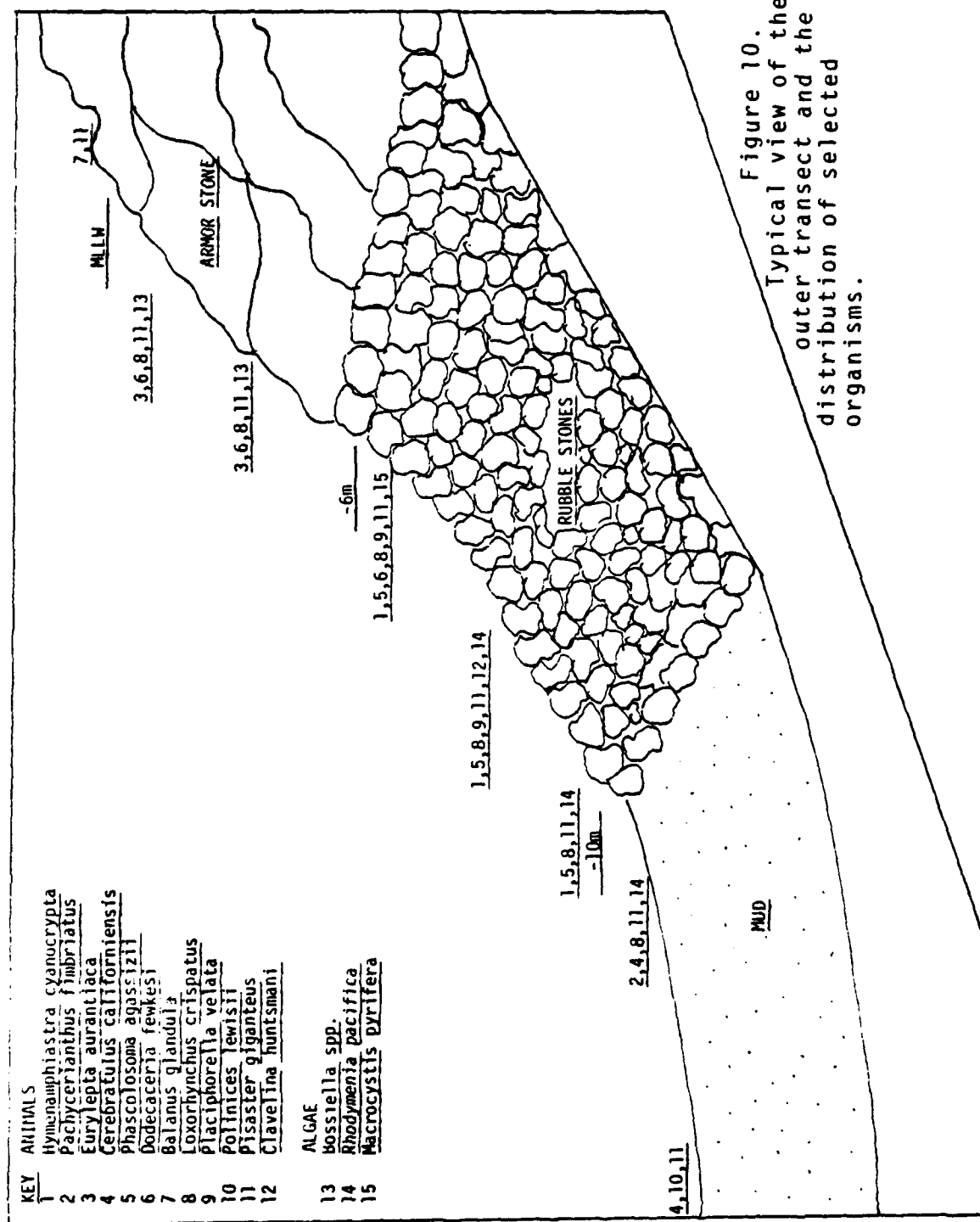
Continuing down the transect there was a steady decline in both species diversity and density. At Q34, it was possible

to reach the mud by excavating 50 cm deep into the rubble. At Q35, some of the animals associated with the mud bottom community first began to appear.

At the base of the breakwater, there was a gradual transition phase between the animals found on the breakwater and those associated with the muddy bottom. The data showed that quadrats Q36-Q38 were the interface area. Along these quadrats the red alga Rhodymenia pacifica decreased in numbers as did the numbers of animals found on the breakwater. At the same time animals associated with the mud began to increase modestly. Finally, at a distance of three meters from the edge of the breakwater, Rhodymenia pacifica occurred only sparingly, due to the lack of stones buried just beneath the mud, and it was here that muddy bottom animals appeared more frequently (i.e. Stylatula elongata, Glycera spp., and Polinices lewisi). Also observed 10 m from the edge of the breakwater, but not within the transect line, was the gaper clam Tresus nuttallii (see Figure 10 for a general overview of selected organisms and their distribution).

C. INNER TRANSECT

The organisms within the intertidal quadrats (S1-S5) were much the same as those within the outer intertidal quadrats, in terms of diversities and densities. The highest sub-tidal quadrats (S6-S9) on the inner breakwater showed major differences from those on the outside. Whereas, the coralline algae were the dominant plants on the outer transect, the browns and



several other reds dominated these shallows on the inside. Large Macrocystis pyrifera and Cystoseira osmundacea were found as shallow as one meter, along with numerous Prionitis lanceolata and Botrycladia pseudodichotoma. This can be associated with the more favorable conditions found in the lee of the breakwater for their holdfast attachment. Also there was a more abrupt increase in the crab and snail populations than was found at the same level on the outer transect. Further down the inner transect, the numbers and diversities approximately mimic the outer transect for the same depths on the armor stones.

Quadrat S16, by coincidence, was also the first quadrat encountered which consisted of rubble but it was only protected by armor stones on two sides. It, too, included substrate occupied by some of the more uncommon animals, Aplysilla polyraphis, Diodora arnoldi, and Evasterias troschelli. Quadrats S17 and S18 had the same plant and animal populations as the outer quadrats Q17 and Q18, except the red alga Rhodomenia pacifica was replaced by the red alga Botrycladia pseudodichotoma and the brown alga Dictyoneuropsis reticulata. The bryozoans Hippodiplosia insculpta and Bugula californica were the dominant invertebrates.

There were fewer quadrats containing rubble on the inner transect than the outer (seven versus 16) and the first two rubble quadrats (S20 and S21) showed greater density and diversity of marine life than the remaining five rubble quadrats. A major difference between these quadrats and those on the

outer transect, was the absence of social and compound ascidians. Quadrats S23 to S26 showed more rapid decline in animal species and individual numbers. The rocks became more and more covered with fine layers of sediment. The red algae diminished not only in numbers but in size.

At the bottom of the inner breakwater there was no gradual interface of animals associated with the rocks and mud. It was an abrupt contrast, with the mud bottom taking on a barren look, with numerous dead Pododesmus cepio shells littering the bottom. The dominant animals were nemerteans, living among the layers of shells and mud, and the terrebellid worm Eupolymnia crescentis. Several snails were also associated with this substrate, including Batillaria attramentaria, Nassarius fossatus, and Pteropurapura trilata (see Figure 11 for selected organisms and their distribution on the inner transect).

D. GENERAL COMPARISONS; OUTER VERSUS INNER TRANSECT

There were a total of 316 species of animals identified, with 202 species common to both inner and outer transects. There were 61 species of animals found only on the outer transect and 53 species found only on the inner transect. The outer transect had 29 species of algae with nine species found only in its area. In comparison, the inner transect had only four of its 24 species of algae unique to the transect (see Tables II and II for listings). Some of these differences can be attributed to the fact that certain animals and plants prefer

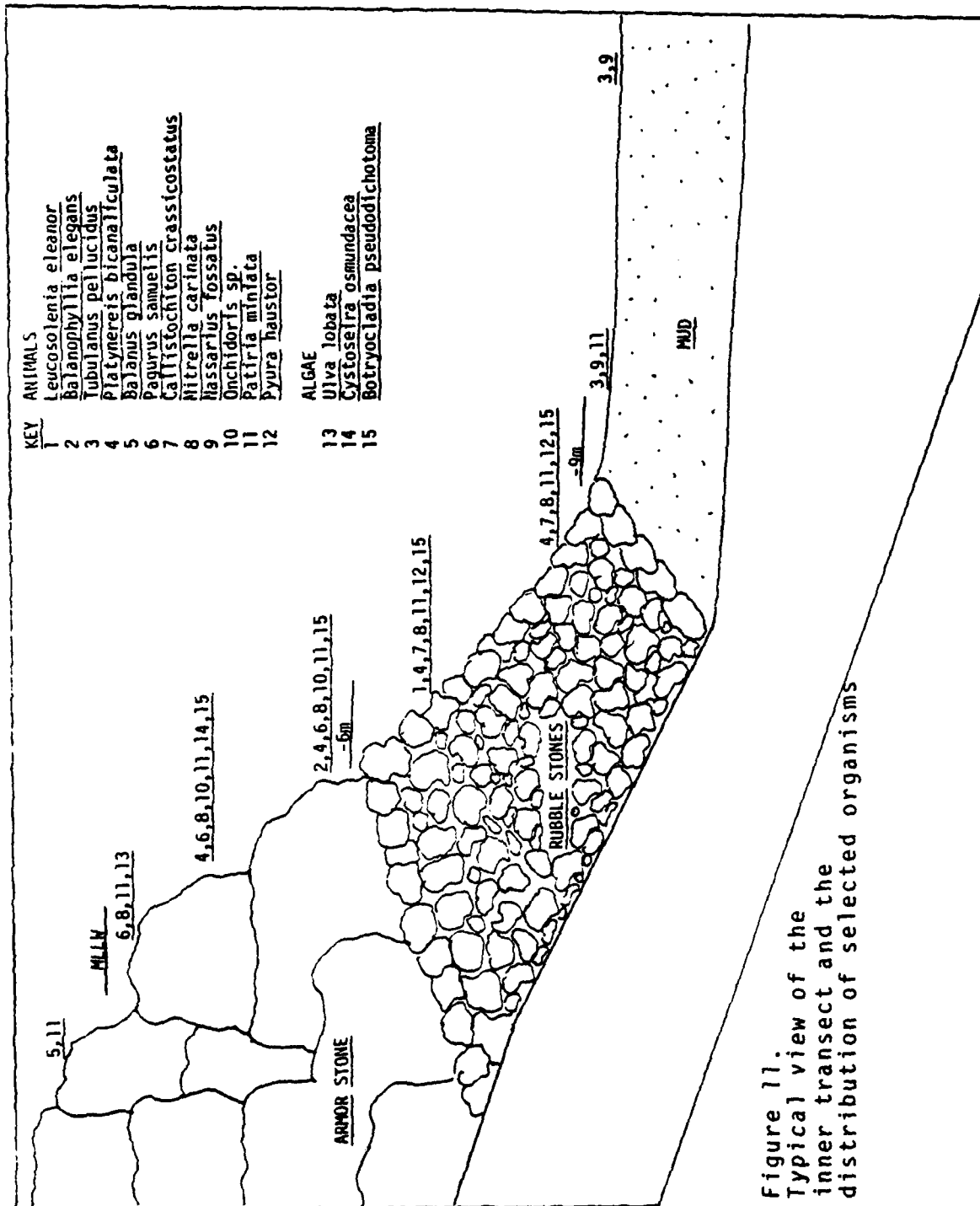


Figure 11.
Typical view of the
inner transect and the
distribution of selected organisms

TABLE II

List of animals and plants found only on the outer transect.

PORIFERA

Sigmatocia sp.
Acarus erithacus
Hymedismia brepha

COELENTERATA

Aglaophenia struthionides
Stylatula elongata
Antopleura artemisia
Metridium exilis
Tealia crassicornis
Tealia coriacea
Tealia lofotensis
Epactis prolifera

PLATYHELMINTHES

Eurylepta aurantiaca

SIPUNCULA

Themiste pyroides

ANNELIDA

Harmothoe imbricata
Autolytus spp.
Euphrosine aurantiaca
Trypanosyllis ingens
Nereis pelagica neonigripes
Glycera americana
Glycera capitata
Pherusa inflata
Axiiothella rubrocincta
Thelepus crispus
Eudistylia polymorpha
Pseudopotamilla intermedia
Pseudopotamilla occelata
Sabella media

ARTHROPODA

Pollicipes polymerus
Heptacarpus brevirostris
Heptacrypta occidentalis
Pinnixa tubicola
Paraxanthias taylori

MOLLUSCA

Stenoplax fallax
Katharina tunicata
Mopalia lignosa
Mopalia lowei
Mopalia porifera
Haliotis walallensis
Astraea gibberosa
Searlesia dira
Petalococonchus montereyensis
Balcis spp.
Policines lewisii
Mitra idae
Alpysia californica
Archidoris odhenri
Discordoris heathi
Pseudochama exogyra

ECTOPROCTA

Hippothoa sp.

ECHINODERMATA

Strongylocentrotus franciscanus
Henricia leviuscula
Leptasterias hexactis
Amphiodia occidentalis
Ophionereis eurybrachyplax

UROCHORDATA

Aplidium californicum
Aplidium solidum
Archidistoma diaphanes
Clavelina huntsmani
Cystodytes lobatus
Cystodytes sp.
Chemidocarpa finmarkiensis

ALGAE ; RHODOPHYTA

Endocladia muricata
Gelidium pusillum
Gigartina corymbifera
Gigartina spinosa
Iridaea cordata
Iridaea lineare
Rhodoglossum californicum
Cryptopleura lobulifera
Botryoglossum farlowianum

TABLE III

List of animals and plants found only on the inner transect.

PORIFERA

Hymeniacidon sp.
Hymendesmia sp.
Aplysilla polyraphis
Sigmatocia edaphus
Halichondria panicea
Haliclona sp.

PLATYHELMINTHES

Stylochoplana gracilis
Hoploplana californica

NEMERTEA

Tubulanus pellucidus
Micrura pardalis
Lineus ruber

ANNELIDA

Lepidasthenia gigas
Anaitides medipapillata
Eulalia virdis
Pionosyllis gigantea
Eusyllis assimilis
Odontosyllis phosphorea
Lumbrineris zonata
Polydora pygidialis
Cautleriella alta
Flabelliderma essenbergae
Pherusa papillata
Pectinaria californensis
Terebella californica
Schizobranchia insignis

ARTHROPODA

Spirontocaris prionota
Cancer jordanii
Pinnixa longipes
Cryptolithodes typicus

MOLLUSCA

Leptochiton rugatus
Diodora arnoldi
Homalopoma baculum
Batillaria attramentaria
Crepidula nummaria

MOLLUSCA (cont.)

Crepidatella lingulata
Nassarius fossatus
Lacuna porrecta
Tricolia pulliodes
Pteropurapura trilata
Mytilus edulis
Cadlina modesta
Cadlina flavomaculata
Onchidoris hystericina
Onchidoris sp.
Melibe leonina
Polycera atra
Triopha maculata

ECTOPROCTA

Crisia occidentalis
Membranipora serrilamella
Lagenipora spinulosa

ECHINODERMATA

Strongylocentrotus sp.
Evasterias troschelli
Parastichopus parimensis

ALGAE

CHLOROPHYTA

Bryopsis corticulans

RHODOPHYTA

Grateloupia doryphora
Prionitis filiformis
Rhodymenia californica

or require more wave action and turbulence than others. Also, near the inner transect there were several pilings from the mooring dolphins on the bottom and it was possible that animals normally associated with piling communities have migrated onto the rocks. One factor that does not appear to contribute to any differences between the animals and plants found on the transects was water quality. Animals associated with well-circulated water did appear on both transects. Some examples were Boltenia villosa and Halocynthia hilgendorfi igaboja (see Abbott and Newberry, 1980). Overall, the differences between the inner and outer transects appeared minor and primarily involved differences in relative abundance of only a few species. Continued study of the breakwater is needed to make additional observations and perhaps extend the list of species found during this investigation.

E. OTHER UNDERWATER OBSERVATIONS

Ten dives, as previously mentioned, were made to record the different species of fish observed along the breakwater. Also, records were kept on interesting events that happened during the course of the quadrat sampling.

A total of 40 species of fish were observed associated with the breakwater, with the majority of the fishes belonging to the rockfish and perch families (see Appendix D for listing). There was a definite demarcation line of the fish populations. Near the shoreward end of the breakwater the diver saw large schools

of perch and blue rockfish, but none were seen beyond the end of the cement roadway on the breakwater. This point was also the western limit of the sea lion population when they were in the water in large groups. The fish population also fluctuated considerably during the period preceeding and just after the sea lion's migration to the Channel Islands in early July. During the months of May and June the sea lion population increased two or threefold from its yearly average of 50-100 animals, as animals from Northern California stopped here to rest on their journey south. The fish responded accordingly and were scarce during this time period. Soon after the sea lions left, the diver saw large schools of fishes all along the 122 m extension, but when the normal population of sea lions returned in late August, the fish returned to their normal demarcation line.

During the course of the quadrat sampling it was not unusual to have up to twenty sea lions around during a dive. There were never any incidents of the sea lions showing hostile or aggressive behavior underwater towards the diver. On the contrary, there was one occasion when a large male actually layed side by side with the diver while the diver sampled quadrat Q38. The sea lion repeated this action three times before presumably tiring of mimicking an almost motionless diver.

The feeding habit of a California sea otter was observed on the completion of quadrat sampling. The diver was swimming up the outer transect, when a sea otter was seen cruising the

bottom. The animal stopped, grabbed a rock with its front paws and preceded to flip the rock over. At this moment, the otter became aware of the diver's presence and left for the surface. Swimming over to the rock, there was still attached a 17.5 cm long red abalone. The dimensions of the rock were 40 by 28 cm and four to six cm in width. The otter showed no difficulty in turning over this sized rock.

V. SUMMARY AND RECOMMENDATIONS

A. SUMMARY

The quadrat stations sampled in this study represented a wide range of environmental conditions. The intertidal zone of a breakwater is a rigorous and variable marine habitat, requiring unique adaptations by the benthic community inhabiting this zone. These organisms must either be able to migrate with the tides or be able to withstand long exposures and rapid fluctuations of a wide range of physical factors. Since, relatively few marine organisms have been able to adapt to these conditions, the diversity of the intertidal benthic community is generally limited, as shown in this study.

Differences in the composition of the benthic community between the transects for the highest subtidal areas reflect differences in water turbulence. With brown algae exhibiting a marked preference for less turbulence. On the rubble stone substrate, the greater depths and the increase in the structural complexity of the rock surface were much more favorable for

the existence of a rich and diverse fauna. The many holes and crevices within the rubble base provided a greater surface area for the attachment of sessile forms as well as shelter for many animals. Also, the presence of a large number of red algae added to this complexity and increased the availability of niches for smaller organisms. Differences between transects along the rubble quadrats appeared minor and primarily involved differences in relative abundance of only a few species. These differences could be attributed to any number of factors.

The mud bottom transects exhibited the major differences with the greater diversity and abundance of benthic organisms found along the outer transect. The scarcity of organisms on the mud of the inner transect may be due to siltation and the corresponding decrease in light intensity at the bottom.

B. RECOMMENDATIONS

Because of the high density and great diversity of shallow-water organisms on the breakwater and other natural reefs, the potential for environmental damage from future coastal engineering projects requires precautions be taken to preserve the ecological integrity of these areas. To assess the environmental impact of such projects, they should be preceded by qualitative and quantitative surveys of the project area. This study has established an initial survey for the Monterey breakwater, but further studies are required to make the survey more complete. Also, comparative studies of the same transect line

should be conducted at intervals of no longer than two years to establish possible patterns in the stability of the benthic community. Specific and more detailed analysis of a smaller transect area (only the rubble core for example) would produce more accuracy in the population numbers as well as allow concentration on any environmental limiting factors. Narrowing the scope further, a study of the interactions of organisms on a single armor stone would be important for adequately describing the dynamics of the community.

APPENDIX A Table of Species:Outer Breakwater

[illegible]

APPENDIX A (cont.)

[illegible]

APPENDIX A (cont.)

[illegible]

APPENDIX A (cont.)

[illegible]

+ Animals (263) cont.	Quadrat #	→	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Lg. Dim. (cm)
Nemertea (6)			6	7	8	9	0	1	2	3	4	5	6	7	8	9	0	0	0	2
Tubulanus sexlineatus					2	1		1												
Cerebratulus californiensis																				
Micrura verrilli																				
Amphiporus imparispinosus	3	.					2									3			3	3
Paranemertes peregrina																		1		2.5
Tetrastemma nigrifrons	2																			2.5
Sipuncula (2)																				
Phascolosoma agassizii	93	4				67	50		42	23	31	46	62	49	53	41	21		2	3.5
Themiste pyroides											1									
Annelida (47)																				
Arctonoe pulchra																				
Hatosynda brevisetosa																				
Harmothoe imbricata																				
Lepidonotus squamatus																				
Euphorisine aurantiaca																				
Anaitides williamsi																				
Eulalia aviculisetia																				
Eulalia bilineata																				
Ophiodromus pugettensis																				
Autolytus spp.																				
Syllis gracilis																				
Trypanosyllis ingons																				
Nereis eakini																				
Nereis pelagica neontripes																				
Platynereis bicanaliculata																				
Glycera americana																				
Glycera capitata																				
Dorvillea monilloceras																				
Arabellia iricolor																				
Boccardia sp.																				
Boccardia tricuspa																				
Polydora convexa																				
Polydora giardi																				
Chaetopterus variegatus																				
Phyllochaetopus prolifica																				
Dodecaceria fewkesi																				
Pherusa inflata																				
Axiostella rubrocincta																				
Phragmatopoma californica																				

[illegible]

APPENDIX A (cont.)

[illegible]

APPENDIX A (cont.)

[illegible]

[illegible]

+ Animals (263) cont.	Quadrat #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	4
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APPENDIX A (cont.)

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APPENDIX A (cont.)

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APPENDIX A (cont.)

→ Algae (29)	Quadrat #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522
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+ Algae (29) cont.	Quadrat # →	Q	Q	Q	Q	Q	Q	Q	Q	Q	Lg. Dim. (cm)
		0	0	0	0	0	0	0	0	0	0
		3	3	3	3	3	3	3	4	4	4
		1	2	3	4	5	6	7	8	9	5

Ulva expansa
Ulva lobata

Ralfsia pacifica
Dismarestia ligulata var. *ligulata*
Dictyonereopsis reticulata
Macrocystis pyrifera
Egretta menziesii
Cystoseira osmundacea

Lithothamnium pacificum
Lithothamnium californicum
Lithothamnium sp.
Corallina officinalis var. *chilensis*

Lithothamnium pacificum	5%	5%	6%	5%	2%	2%	4
Lithothamnium californicum	17%	31%	19%	12%	5%		4
Lithothamnium sp.	7%	8%	1%	2%	1%		4
Corallina officinalis var. chilensis							3
Bossiella californica							
Bossiella chiloensis							
Bossiella orbigniana							
Endocladia muricata							
Geldium pusillum							
Gigartina exasperata							
Gigartina corymbifera							
Gigartina spinosa							
Iridaea lineare							
Iridaea cordata							
Iridaea flaccida							
Prionitis lanceolata							
Rhodoglossum californicum	3	2	1				10
Cryptopleura lobulifera	1	1					20
Botryocladia pseudodichotoma							
Botryoglossum farlowianum	33	41	49	63	53	21	15
Rhodymenia pacifica							

APPENDIX B Table of Species; Inner Breakwater
The species listed in accordance with quadrat location

+ Animals (255)	Quadrat #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000
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[illegible][illegible]

[illegible]

[illegible]

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APPENDIX B (cont.)

Animals (255)	Quadrat #	1	2	3	4	5	6	7	8	9	10	11	12	Lg. Dim. (cm)
Annelida (47) cont.														
<i>Flabelligerina essenbergae</i>							1							2
<i>Pherusa papillata</i>														
<i>Eusyllis assimilis</i>														
<i>Phragmatopoma californica</i>	87	63	14											2.5
<i>Sabellaria cementarium</i>	9	14	6			3	3	4	3		2			2
<i>Sabellaria gracilis</i>														
<i>Pectinaria californiensis</i>														
<i>Pista elongata</i>														
<i>Eupolymnia crescentis</i>										6				5
<i>Neomphithrite robusta</i>														
<i>Terebella californica</i>														
<i>Sabella crassicornis</i>							3	5			1			2.5
<i>Schizobranhia insignis</i>										4				1.5
<i>Crucigera zygophora</i>														
<i>Serpula vermicularis</i>	49	61	75	18	51	96	115	214	91	103	68	113	2	
<i>Chitonopoma groenlandica</i>	7	16	4		2	18	33	41	2	6	5	3	1.5	
<i>Circeis armoricana</i>	A	A	A	A	A	A	A	A	A	A	A	A	.5	
<i>Jana nipponica</i>	A	A	A	A	A	A	A	A	A	A	A	A	.5	
<i>Pilodaria potswaldi</i>	A	A	A	A	A	A	A	A	A	A	A	A	.5	
<i>Protolaespira exima</i>	A	A	A	A	A	A	A	A	A	A	A	A	.5	
Arthropoda (49)														
<i>Copepoda</i>														
<i>Balanus aquila</i>														.1
<i>Balanus crenatus</i>														5
<i>Balanus glandula</i>														2
<i>Balanus nubilis</i>						16	23	26	14	16				1.5
<i>Megabalanus californicus</i>	715	215	330	263			3	3	1					7
<i>Chthamalus</i>	14	8	16	12										2.5
<i>Tetraclita rubescens</i>	431	95	260	116	86	35								.5
<i>Synidotea ritteri</i>	1130	145	860	257	312	123								3
<i>Synidotea sp.</i>														.5
<i>Paracerceis cordata</i>	2	1												.5
<i>Podocerus sp.</i>										1	1	3		.7
<i>Deutella californica</i>														.3
<i>Tritella pilimana</i>														.5
<i>Caprella californica</i>														.5
<i>Caprella equilibra</i>														.5
<i>Caprella ferrea</i>														.5
<i>Caprella sp.</i>														.5
<i>Thalassacarus sp.</i>														.3

[illegible]

Copepoda

	1	4	1	12	6	3	3	8	1	9	5	2	2	7
Balanus aquila	1													
Balanus crenatus														
Balanus glandula														
Balanus nubilis														
Megabalanus californicus														
Citharus dalli														
Tetraclita rubescens														
Synidotea ritteri														
Synidotea sp.														
Paracerceis cordata														
Podocerus sp.														
Deutella californica	P	P		P		P	P	P	P	P	P	P	P	.3
Tritella pilimana	P			P		P			P					.5
Caprella californica								P			P			.5
Caprella equilibra	P	P			P	P			P			P		.5
Caprella ferrea				P	P	P								.5
Caprella sp.	P	P		P	P	P	P	P	P	P	P	P	P	.5
Thalassacarus sp.	22	18	67			10								.3

[illegible]

Flabelliderna essenbergae
Pherusa papillata
Eusyllis assimilis
Prinematopoma californica
Sabellaria cementarium
Sabellaria gracilis
Pectinaria californiensis
Pista elongata
Eupolyomia crescentis
Meoamphitrite robusta
Terebella californica
Sabella crassicornis
Schizobranchia insignis
Crucigera zygophora
Serpula vermicularis
Chitonopoma groenlandica
Circeis armoricana
Jana nipponica
Ptilodaria potswaidi
Protolaeospira exima

Copepoda
Balanus aquila
Balanus crenatus
Balanus glandula
Balanus nubilus
Megabalanus californicus
Ctenochinus dalli
Tetracella rubescens
Synidotea ritteri
Synidotea sp.
Paracercis cordata
Podocerus sp.
Deutella californica
Tritella pilimana
Caprella californica
Caprella equilibra
Caprella ferrea
Caprella sp.
Thalassacarus sp.

[illegible]

[illegible]

Octopus sp.
Callistochiton crassicosatus
Mutallina californica
Cyanoplax dentiens
Ischnochiton radians
Ischnochiton regularis
Lepidozona cooperi
Lepidozona mertensii
Stenoplax heathiana
Tonicella lineata

[illegible]

APPENDIX B (cont.)

+ Animals (255)	Quadrat #→	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	Lg.
		1	2	3	4	5	6	7	8	9	0	1	2	(cm)					Dim.
Mollusca (74) cont.																			
Leptochiton rugatus																			
Mopalia ciliata	1	3	1				4	2	1	2		2							3.5
Mopalia muscosa																			8
Placiphorella velata																			
Haliotis cracherodii	3		1																8
Haliotis rufescens	1	2					3	4	2	1			1						20
Diodora arnoldi																			
Fissurella volcano																			
Megathura crenulata																			
Acmaea mitra						5	9	11	5	1		1	5						15
Collisella digitalis	148	12	97	44															2.5
Collisella ochracea							3	1											1
Collisella pelta						2	5	3											1.5
Collisella scabra	314	41	169	13															1
Collisella triangularis		1	1																1
Lottia gigantea	2	6	1	4															1.5
Notoacmea persona	5																		3
Notoacmea scutum	3	24	18	14	19	7	5	6	3	1									1
Callioostoma annulatum																			2
Callioostoma canaliculatum								1											3
Callioostoma ligatum		3	1			2	2	5		2		4	2		3				2.5
Tegula brunnea	4	3	1		5														3
Tegula funebris						1													3
Tegula montereyi																			3
Homalopoma baculum								3		4		2							1
Homalopoma luridum							6	5	7										1
Lacuna porrecta						4				1									1
Tricolia pulloides								2											1.5
Littorina planaxis	23		14	12															1
Littorina scutellata	6		3																.5
Serpulorbis squamigerus	1			5	3	2	2	6	11	5		6	4		5				6
Batillaria attramentaria									4										1.5
Crepidula adunca																			1
Crepidula nummaria																			1
Crepidatella lingulata																			1
Ceratostoma foliatum																			1
Ocenebra interfossa																			1
Amphissa versicolor																			1
Mitrella aurantiaca																			1
Mitrella carinata																			1
Nassarius fossatus																			1
Fusinus luteopictus																			1
Pteropurapura trilata																			1

[illegible]

APPENDIX B (cont.)

Animals (255)	Quadrat # +	5	6	7	8	9	0	1	2	3	4	5	6	Lg. Dim. (cm)
Mollusca (74) cont.														
Leptochiton rugatus		2	2	1										1
Mopalia ciliata														
Mopalia muscosa														
Placiphorella velata														
Haliotis cracherodii														
Haliotis rufescens														
Diodora arnoldi														
Fissurella volcano														
Megathura crenulata														
Acmaea mitra		3	1	1										2.5
Collisella digitalis														
Collisella ochracea														
Collisella pelta														
Collisella scabra														
Collisella triangularis														
Lottia gigantea														
Notoacmea persona														
Notoacmea scutum														
Calliostoma annulatum														
Calliostoma canaliculatum														
Calliostoma ligatum														
Tegula brunnea														
Tegula funebris														
Tegula montereyi														
Homalopoma baculum		1	2											1
Homalopoma luridum														
Lacuna porrecta														
Tricolia pulloides														
Littorina planaxis														
Littorina scutulata														
Serpulorbis squamigerus														
Batillaria attramentaria		12	4	5	6	3	2	1	1	1	4	2	1.5	
Crepidula adunca														
Crepidula nummaria														
Crepidula lingulata														
Ceratostoma foliatum														
Ocenebra interfossa														
Amphissa versicolor		7	3	1										1
Mitrella aurantiaca														
Mitrella carinata		2	3	6	5	4	3	2	1	1	3	1	2	
Nassarius fossatus														
Fusinus luteopictus		2	4	3	2	5	2	1	1	1	1			3.5
Pteropurapura trilata														

[illegible]

APPENDIX B (cont.)

+ Animals (255)	Quadrat # +	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	Lg. Dim. (cm)
Mollusca (74) cont.																				
<i>Anisodoris nobilis</i>		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	5
<i>Archidoris montereyensis</i>																				
<i>Cadlina flavomaculata</i>																				
<i>Cadlina modesta</i>																				
<i>Diaulula sandiegensis</i>																				
<i>Doriopsilla albopunctata</i>		1	3	3	2															2.5
<i>Coryphella pricei</i>																				2.5
<i>Hermisenda crassicornis</i>			1																	1.5
<i>Onchidoris hystrixina</i>		6	3	9	4	1	2	6												1
<i>Onchidoris</i> sp.																				
<i>Melibe leonina</i>																				
<i>Polycera atra</i>		1			2															.5
<i>Rostanga pulchra</i>																				1.5
<i>Triopha catalinae</i>																				1
<i>Triopha maculata</i>		2		1																1
<i>Hinnites giganteus</i>		1		1																12
<i>Pododesmus cepho</i>		17	21	6	1	7	12	23												11
<i>Mytilus californianus</i>																				
<i>Mytilus edulis</i>																				
<i>Chama arcana</i>					1															3
<i>Irus lamellifer</i>																				
Ectoprocta (17)																				
<i>Bowerbankia gracilis</i>	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	1
<i>Crista maxima</i>																				
<i>Crista occidentalis</i>																				
<i>Crisulipora occidentalis</i>																				2
<i>Diaperoecia californica</i>	3	4	14	29	44	63	112	96	23	33	51	21	6	8	4	3	4	3	4	3.5
<i>Bugula californica</i>	85	69	114	813	631	21	113	6	1	1	7	8	4	3	4	3	4	3	4	2.5
<i>Bugula neritina</i>	21	4	4	1	3	6	11	17												4.5
<i>Lyrula hippocrepis</i>																				3.5
<i>Membranipora serrilamella</i>																				
<i>Reginella nitida</i>	11	16	14	8	9	16	13	15												4.5
<i>Celleporaria brunnea</i>	23	19	4	4	7	3	3	3												3.5
<i>Cryptosula pallasiaca</i>																				
<i>Coleopora gigantea</i>		6	13	17	39	8	6	11	14	21	16	17								3
<i>Eurystomella bilabiata</i>																				
<i>Hippodipsosia insculpta</i>																				
<i>Lagenipora spinulosa</i>																				
<i>Phidolopora pacifica</i>																				

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APPENDIX B (cont.)

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TABLE IV

Explanation of symbols₂ used in Appendix A and B for organisms collected in the 1.0 m² samples.

Symbol	Descriptive Term	Explanation
A	Abundant	Numbers given in Appendix C
P	Present	Numbers were impossible to determine

APPENDIX C SPECIES LIST

ANIMALS

PORIFERA

DEMOSPONGIAE

Halisarca sp. Found predominantly along the outer transect, under the first layer of rubble stones.

Aplysilla polyraphis de Laubenfels, 1930. Rare, a single specimen was found 30 cm deep in the rubble on the inner transect.

Haliclona sp. Found in a cave on the inner transect.

Reniera sp.

Xestospongia vanilla (de Laubenfels, 1930).

Sigmatocia edaphus de Laubenfels, 1930. Rare. Two specimens were collected under the first layer of rubble on the inner transect.

Sigmatocia sp.

Zygherpe hyaloderma de Laubenfels, 1932.

Axocielita originalis (de Laubenfels, 1930). Common along both transects, on undersides of the rubble. Rostanga pulchra was observed feeding on A. originalis on two occasions.

Ophlitaspongia pennata (Lambe, 1895). Found in small crevices and under overhangs of the armor stones on both transects.

Acarnus erithasus de Laubenfels, 1927. Uncommon.

?Astylinifer arndti de Laubenfels, 1930.

Hymedesmia brepha (de Laubenfels, 1930). Rare. Collected on the sides of uncovered rubble stones.

Hymedesima sp.

Hymenamphiastra cyanocrypta de Laubenfels, 1930. Found at depths below four meters and only on the rubble stones along both transects.

Lissodendoryx topsenti (de Laubenfels, 1930).

Halicnondria panicea (Pallas, 1766). Found only along the inner transect on the armor stones, in well-lighted situations.

Hymeniacion ungodon de Laubenfels, 1932.

Hymeniacion sp. Collected from the undersides of a 75 cm long overhang on an armor stone along the inner transect.

Cliona ?celata Grant, 1826.

Cliona spp. Found predominantly on dead Balanus nubilus shells that have fallen off the mooring dolphins along the inner transect.

Stelletta clarella de Laubenfels, 1930. Specimens were collected down to 75 cm in the rubble on both transects.

CALCAREA

Leucosolenia eleanor Urban, 1905. Numbers tabulated refer to the individual clusters of anastomosing tubes. Common on the stipes of the red algae.

Leucandra heathi Urban, 1905.

COELENTERATA

HYDROZOA

Aglaophenia struthionides (Murray, 1860). Observed along the outer transect only.

Aglaophenia latirostris Nutting, 1900. Common on red algae, in large clusters, along both transects.

Plumularia spp. Present throughout the transects. Their delicate nature made numerical determinations impossible.

Sertularella spp. The most common and widely distributed hydroid on the transects.

ANTHOZOA

Anthopleura artemisia (Pickering in Dana, 1848).

Anthopleura elegantissima (Brandt, 1835).

Anthopleura xanthogrammica (Brandt, 1835).

Epiactis prolifera Verrill, 1869. Found on the undersides of the rubble, along the outer transect to a depth of two meters.

Tealia coriacea (Cuvier, 1798). Observed in the mud on the outer transect only.

Tealia crassicornis (Muller, 1776). Found on the side of a large rubble stone along the outer transect at a depth of eight meters.

Tealia lofotensis (Danielssen, 1890). A single juvenile specimen was found along the outer transect. All the members of the genus Tealia were conspicuously absent along the inner transect.

Metridium exilis Hand, 1955.

Metridium senile (Linnaeus, 1767). Found in sheltered caves on both transects.

Balanophyllia elegans Verrill, 1864. Common, on the vertical protected faces of the armor stones. On the inner transect (see Appendix B, S15) 873 of the 889 specimens were juveniles and pure white in color. This phenomenon was observed on almost every similar armor stone along the length of the inner breakwater, at this depth.

Corynactis californica Carlgren, 1936.

Pachycerianthus fimbriatus McMurrich, 1910. Several specimens exhibited high degrees of variance and were synonymous with P. torreyi. See Arai (1965).

Stylatula elongata (Gabb, 1863).

PLATYHELMINTHES

POLYCLADIDA

Hoploplana californica Hyman, 1953. Found among the dead Pododesmus cepio shells scattered about the mud along the inner transect.

Stylochoplanea gracilis Heath and McGregor, 1912. Found on the stipe and blade of a small Macrocystis pyrifera.

Stylochus tripartitus Hyman, 1953. All specimens were collected off the armor stones. S. tripartitus is normally found on kelp stipes and holdfasts (see Haderlie (1975) in Light's Manual). However, the quadrats where S. tripartitus were found are occasionally covered by drifting Macrocystis pyrifera being washed up and over the breakwater. This would account for its presence through these quadrats.

Eurylepta aurantiaca (Heath and McGregor, 1912). On quadrats Q7-Q12 there were a large number of this flatworm found. A single 10 cm² grid yielded 35 specimens, the largest being only seven mm. Even with the thinnest collecting spatula, E. aurantiaca was hard to remove from the rocks. Based on the single 10 cm² grid and other observations, the population of E. aurantiaca was conservatively estimated to exceed 300 per m², for the six quadrats.

NEMERTEA

ANOPLA

Tubulanus pellucidus (Coe, 1895). Found in delicate tubes under the dead Pododesmus cepio shells on the mud of the inner transect.

Tubulanus sexlineatus (Griffin, 1898). Found only on the armor stones on both transects.

Cerebratulus californiensis Coe, 1905.

Lineus ruber (O.F. Muller, 1771).

Micrura verrilli Coe, 1901. Two specimens were found beneath rubble stones that were wedged inbetween armor units on the inner transect.

Micrura pardalis Coe, 1905.

ENOPLA

Amphiporus imparispinosus Griffin, 1898.

Paranemertes peregrina Coe, 1901.

Tetrastemma nigrifrons Coe, 1904. Found in algal holdfasts.

SIPUNCULA

GOLFINGIIDAE

Themiste pyroides (Chamberlain, 1919). One specimen was found 40 cm deep in the rubble on the outer transect.

PHASCOLOSOMATIDAE

Phascolosoma agassizii Keferstein, 1867. Found throughout the transects in crevices, shells and holdfasts.

ANNELIDA

POLYCHAETA (Most diverse group observed and is presented here using the family format listed by Blake (1975) in Light's Manual).

POLYNOIDAE

Arctonoe pulchra (Johnson, 1897). Commensal with Neoamphitrite robusta.

Halosydna brevisetosa Kinberg, 1855. Most common scale worm found.

Harmothoe imbricata (Linnaeus, 1767).

Lepidonotus squamatus (Linnaeus, 1767).

Lepidasthenia gigas (Johnson, 1897). Commensal with Neoamphitrite robusta on the inner transect. Hartman (1968, p. 113) lists L. gigas range as limited to Southern California.

EUPHROSINIDAE

Euphrosine aurantiaca Johnson, 1897. Always found under the first layer of rubble on the outer transect. See Hartman (1968).

PHYLLODOCIDAE

Anaitides medipapillata Moore, 1909.

Anaitides williamsi Hartman, 1936.

Eulalia aviculiseta Hartman, 1936.

Eulalia bilineata (Johnson, 1840). Found in algal holdfast.

Eulalia virdis (Linnaeus, 1767).

HESIONIDAE

Ophiodromus pugettensis (Johnson, 1901). One specimen was found free living. All others were observed in ambulacral grooves of Patiria miniata.

SYLLIDAE

Autolytus spp.

Eusyllis assimilis Marenzeller, 1875. See Hartman (1968).

Odontosyllis phoshporea Moore, 1909. Found among algal holdfasts, only on the inner transect.

Pionosyllis gigantea Moore, 1908.

Syllis gracilis Grube, 1840. Predominately found in crevices between armor stones.

Trypanosyllis ingens Johnson, 1902.

NEREIDAE

Nereis eakini Hartman, 1936.

Nereis pelagica neonigripes Hartman, 1936.

Platynereis bicanaliculata (Baird, 1863). Dominant Polychaeta Errantia on both transects.

GLYCERIDAE

Glycera americana Leidy, 1855.

Glycera capitata Oersted, 1843. Both Glycera were found only in the mud on the outer transect.

DORVILLEIDAE

Dorvillea moniloceras (Moore, 1909). Both specimens were found inside dead Balanus aquila shells.

LUMBRINERIDAE

Lumbrineris zonata (Johnson, 1901). Specimens were excavated at depths in excess of 50 cm from quadrats that had rubble and muddy sediments mixed together.

ARABELLIDAE

Arabella iricolor (Montagu, 1804).

SPIONIDAE (All the species listed below were found boring into the shells of Pododesmus cepio or into coralline algae.)

Boccardia tricuspa (Hartman, 1939).

Boccardia sp. Several specimens were too small for species placement.

Polydora convexa Blake and Woodwick, 1972.

Polydora giardi Mesnil, 1896.

Polydora pygidialis Blake and Woodwick, 1972.

CHAETOPTERIDAE

Chaetopterus variopedatus (Renier, 1804). Found most often at depths below eight meters.

Phyllochaetopterus prolifica Potts, 1914. Common throughout the transects. When found under rocks, the aggregate of tubes usually numbered less than ten.

CIRRATULIDAE

Caulleriella alata (Southern, 1914). See Hartman (1969).

Dodecaceria fewkesi Berkeley and Berkeley, 1954. The most abundant annelid encountered, with large calcareous masses formed on the vertical faces of the armor stones.

FLABELLIGERIDAE

Flabelliderma essenbergae Hartman, 1961. A single specimen was found among the holdfast of Macrocystis pyrifera on the inner transect. Hartman (1960, p. 287) lists its range as Southern California.

Pherusa inflata (Treadwell, 1914).

Pherusa papillata (Johnson, 1901).

MALDANIDAE

Axiothella rubrocincta (Johnson, 1901).

SABELLARIIDAE

Phragmatopoma californica (Fewkes, 1889).

Sabellaria cementarium Moore, 1906. Common throughout both transects, especially on the undersides of rocks.

Sabellaria gracilis Hartman, 1944.

PECTINARIIDAE

Pectinaria californiensis Hartman, 1941. Found on the mud, only along the inner transect.

TEREBELLIDAE

Eupolymnia crescentis Chamberlin, 1919.

Neoamphitrite robusta (Johnson, 1901). The dominant Terebellid found on the breakwater.

Pista elongata Moore, 1909.

Thelepus crispus Johnson, 1901.

Terebella californica Moore, 1904. Found in algal holdfast.

SABELLIDAE

Eudistylia polymorpha (Johnson, 1901). A single specimen was found on the vertical face of an armor stone on the outer transect.

Pseudopotamilla intermedia Moore, 1905.

Pseudopotamilla ocellata Moore, 1905.

Sabella crassicornis Sars, 1851.

Sabella media (Bush, 1904).

Schizobranchia insignis Bush, 1904.

SERPULIDAE

Crucigera zygophora (Johnson, 1901). Uncommon.

Serpula vermicularis Linnaeus, 1767. Found on all rocks.

Chitonopoma groenlandica (Morch, 1863). See Hartman (1969).

SPIRORBIDAE (See Knight-Jones, 1979)

Circeis armoricana Saint-Joseph 1894. The second most common Spirorbidae, averaging 276 individuals per m² on the armor units and 46,000 per m² along the rubble quadrats.

Jana nipponica (Okuda, 1934). The least common of the four species found. Averaging only 68 per m² on the armor units and 7,000 per m² in the rubble.

Pilodaria potswaldi Knight-Jones, 1978. The dominant Spirorbidae found. Averaging 800 per m² on the armor stones and 100,000 per m² in the rubble.

Protolaeospira exima (Bush, 1904). The third most common species found. Averaging 140 per m² on the armor stones and 18,000 per m² in the rubble.

ARTHROPODA (Crustaceans, the only class present, is presented by sub-families using the format in Smith and Carlton (1975) Light's Manual.)

CRUSTACEA

COPEPODA (Specimens of different genera were collected by accident when larger animals or algae were placed in containers. One species was observed in the matrix of the ascidian Aplidium solidum. Illg (1975) in Light's Manual lists Pholeterides furtiva as being found in A. solidum, but no positive identification was possible.)

CIRRIPEDIA

Pollicipes polymerus Sowerby, 1833. Specimens were found only on the exposed vertical faces of the intertidal armor stones on the outer transect.

Balanus aquila Pilsbry, 1907.

Balanus crenatus Bruguière, 1789.

Balanus nubilus Darwin, 1854. Found only intermittently, except for Q19, a large overhanging ledge, where the undersides had 13 individuals per m².

Balanus glandula Darwin, 1854. Extremely abundant in the high intertidal forming dense stands along with C. dalli.

Megabalanus californicus (Pilsbry, 1916). Found only in crevices or on the undersides of the armor stones. Low intertidal.

Chthamalus dalli Pilsbry, 1916.

Tetraclita rubescens Darwin, 1854.

MALACOSTRACA

Synidotea ritteri Richardson, 1904. Found on Aglaophenia spp.

Synidotea sp. Unable to identify to species due to size and systematic complexity

Paracerceis cordata (Richardson, 1899).

Podocerus sp. Common, found on hydroid Sertularella spp.

Deutella californica Mayer, 1890.

Tritella pilimana Mayer, 1890.

Caprella californica Stimpson, 1857.

Caprella equilibra Say, 1818.

Caprella ferrea Mayer, 1903.

Caprella sp. Unable to identify to species due to size or systematic complexity.

Pandalus danae Stimpson, 1857.

Heptacarpus brevirostris (Dana, 1852).

Heptacarpus pictus (Stimpson, 1857).

Spirontocaris prionota (Stimpson, 1864). Two specimens were found along the inner transect.

Alpheus spp. Common throughout the transect. Their mobility precluded any enumerations.

Heterocrypta occidentalis (Dana, 1854). Present only on the mud bottom of the outer transect.

Loxorhynchus crispatus Stimpson, 1857.

Loxorhynchus grandis Stimpson, 1857. See Schmitt (1921).

Mimulus foliatus Stimpson, 1860.

Pugettia gracilis Dana, 1851.

Pugettia products (Randall, 1839).

Pugettia richii Dana, 1851.

Cancer antennarius Stimpson, 1856.

Cancer jordani Rathbun, 1900. Specimens were found only on the vertical faces of the armor stones along the inner transect. See Schmitt (1921).

Cancer productus Randall, 1839.

Lophopanopeus bellus (Stimpson, 1860).

Lophopanopeus leucomanus heathii Rathbun, 1900.

Paraxanthias taylori (Stimpson, 1860). A single specimen was excavated from a depth of 15 cm in the rubble of Q16.

Pinnixa franciscana Rathbun, 1918. Found in the tubes of the Terebellid Neoamphitrite robusta.

Pinnixa longipes (Lockington, 1877). Found with the annelid Pectinaria californiensis.

Pinnixa tubicola Holmes, 1895. Found in the tubes of Eupolymania crescentis.

Pachygrapsus crassipes Randall, 1839.

Pagurus beringanus (Benedict, 1892). Found only on the rubble or mud, in water depths greater than six m.

Pagurus granosimanus (Stimpson, 1859).

Pagurus hirsutiusculus (Dana, 1851).

Pagurus samuelis (Stimpson, 1857).

Acantholithodes hispidus (Stimpson, 1860). Two specimens were found, one on each transect, in water depths greater than six m. Both were excavated from the rubble 15 cm deep where they were hiding in small dark crevices. See Schmitt (1921).

Cryptolithodes sitchensis Brandt, 1853.

Cryptolithodes typicus Brandt, 1853. See Schmitt (1921).

Hapalogaster cavicauda Stimpson, 1859. Uncommon, found normally at depths in excess of 15 cm in the rubble.

Pachycheles pubescens Holmes, 1900.

Pachycheles rudis Stimpson, 1859.

Petrolisthes cinctipes (Randall, 1839).

Petrolisthes rathbunae Schmitt, 1921.

HALACARIDAE (Mites were observed subtidally on the coralline algae. Newell (1975) in Light's Manual lists Thalassacarus spp. as being known only from this region.)

MOLLUSCA

CEPHALOPODA

Octopus sp. Small specimens observed were believed to be O. rubescens. The one large specimen (77 cm) may have been O. dofleini or O. dofleini martini. See Hochberg and Fields (1980).

POLYPLACOPHORA

Callistochiton crassicostatus Pilsbry, 1893. Most abundant chiton found, occurring from under the first layer of rubble down to the greatest depth excavated (83 cm).

Nuttallina californica (Reeve, 1847).

Cyanoplax dentiens (Gould, 1846).

Ischnochiton radians Carpenter in Pilsbry, 1892.

Ischnochiton regularis (Carpenter, 1855).

Lepidozona cooperi (Pilsbry, 1892).

Lepidozona mertensii (Middendorff, 1846).

Stenoplax fallax (Pilsbry, 1892).

Stenoplax heathiana Berry, 1946.

Tonicella lineata (Wood, 1815).

Leptochiton rugatus (Pilsbry, 1892).

Katharina tunicata (Wood, 1815). Two small specimens were found on the exposed armor rocks on the outer transect.

Mopalia ciliata (Sowerby, 1840).

Mopalia lignosa (Gould, 1846).

Mopalia lowei Pilsbry, 1918.

Mopalia muscosa (Gould, 1846).

Mopalia porifera pilsbry, 1893.

Placiphorella velata Dall, 1879. Common in the rubble, especially on vertical surfaces buried by one or more layers of rubble.

GASTROPODA

Haliotis cracherodii Leach, 1814.

Haliotis rufescens Swainson, 1822. Common throughout the transect. Large specimens were normally found in the crevices of the armor stones. Juveniles averaged three per m² in the rubble quadrats, with several specimens excavated at depths in excess of 60 cm in the rubble core. Frequently, sea otters were seen feeding on H. rufescens. However, based on the numbers of abalone counted and others seen during the study, a conservative estimate of the red abalone population on the 122 m extension exceeds 10,000.

Haliotis walallensis Stearns, 1899.

Diodora arnoldi McLean, 1966. Specimens were found on the inner transect only and in a single group of three. They were excavated from a depth of 20 cm in the rubble. See McLean (1966).

Fissurella volcano Reeve, 1849.

Megathura crenulata Sowerby, 1825.

Acmaea mitra Rathke, 1833.

Collisella digitalis (Rathke, 1833).

Collisella ochracea (Dall, 1871).

Collisella pelta (Rathke, 1833).

Collisella scabra (Gould, 1846).

Collisella triangularis (Carpenter, 1864).

Lottia gigantea Sowerby, 1834.

Notoacmea persona (Rathke, 1833). Specimens were found on the undersides of ledges along the intertidal armor stones.

Notoacmea scutum (Rathke, 1833).

Calliostoma annulatum (Lightfoot, 1786).

Calliostoma canaliculatum (Lightfoot, 1786).

Calliostoma ligatum (Gould, 1849). Common throughout both transects.

Tegula brunnea (Philippi, 1848).

Tegula funebris (A. Adams, 1855).

Tegula montereyi (Kiener, 1850).

Astraea gibberosa (Dillwyn, 1817).

Homalopoma baculum (Carpenter, 1864).

Homalopoma luridum (Dall, 1885).

Tricolia pulloides (Carpenter, 1865).

Lacuna porrecta Carpenter, 1864. Found on drifting eel-grass Zostera sp. that had settled on the bottom along the inner transect.

Littorina planaxis Philippi, 1847.

Littorina scutulata Gould, 1849.

Petalocochus montereyensis Dall, 1919. Two specimens were found on a subtidal ridge (-1 m) on an armor stone along the outer transect.

Serpulorbis squamigerus (Carpenter, 1857).

Batillaria attramentaria (Sowerby, 1855). Specimens were normally found in mud that had collected inside of dead Balanus aquila and B. nubilus shells on the inner transect.

Balcis sp. Single specimen was found in the holdfast of Macrocystis pyrifera.

Crepidula adunca Sowerby, 1825. Found on Calliostoma ligatum, Haliotis rufescens and Tegula funebris.

Crepidatella lingulata (Gould, 1846). Specimens were found on the horizontal surfaces of the armor stones along the inner transect. All were completely encrusted with Lithothamnium sp.

Crepidula nummaria Gould, 1846.

Polinices lewisii (Gould, 1847).

Ceratostoma foliatum (Gmelin, 1791).

Ocenebra interfossa Carpenter, 1864.

Searlesia dira (Reeve, 1846).

Amphissa versicolor Dall, 1871.

Mitrella aurantiaca Hinds, 1844.

Mitrella carinata (Hinds, 1844).

Nassarius fossatus (Gould, 1850).

Fusinus luteopictus (Dall, 1877).

Pteropurapura trilata (Sowerby, 1841). See Abbott and Haderlie (1980).

Mitra idae Melville, 1893. See Abbott and Haderlie (1980).

OPISTHOBRANCHIA

Aplysia californica Cooper, 1863.

Anisodoris nobilis (MacFarland, 1905).

Archidoris odhenri (MacFarland, 1966).

Archidoris montereyensis (Cooper, 1862).

Cadlina modesta MacFarland, 1966.

Cadlina flavomaculata MacFarland, 1905.

Coryphella pricei MacFarland, 1966.

Diaulula sandiegensis (Cooper, 1862).

Discodoris heathi MacFarland, 1905.

Doriopsilla albopunctata (Cooper, 1863).

Hermisenda crassicornis (Eschscholtz, 1831).

Melibe leonina (Gould, 1852). Small specimen was found on the blade of a small Macrocystis pyrifera.

Onchidoris hystericina (Bergh, 1878).

Onchidoris sp. Common on the armor stones of the inner transect. Always found on or near the bryozoan Reginella. See McDonald and Nybakken (1980).

Polycera atra MacFarland, 1905. All specimens were found on the bryozoan Bugula neritina.

Rostanga pulchra MacFarland, 1905. Found on the following sponges, Acarnus erithacus, Ophlitaspongia pennata, Axocielita originalis and Lissodendoryx topsenti.

Triopha catalinae (Cooper, 1863).

Triopha maculata MacFarland, 1905.

BIVALVIA

Irus lamellifer (Conrad, 1837).

Mytilus californianus Conrad, 1837.

Mytilus edulis Linnaeus, 1758.

Chama arcana Bernard, 1976.

Pseudochama exogyra (Conrad, 1837).

Pododesmus cepio (Gray, 1850). Common throughout both transects. The dead shells littering the mud of the inner transect probably came from the mooring dolphins that were removed in the Spring of 1980.

ECTOPROCTA

CTENOSTOMATA

Bowerbankia gracilis O'Donoghue, 1926.

CYCLOSTOMATA

Crisia maxima Robertson, 1910.

Crisia occidentalis Trask, 1857. See Osburn (1953).

Crisulipora occidentalis Robertson, 1910.

Diaperoecia californica (d'Orbigny, 1852). Abundant. Found predominantly encrusting the stipes of red algae.

CHEILOSTOMATA

Bugula californica Robertson, 1905.

Bugula neritina Linnaeus, 1758.

Lyrula hippocrepis (Hincks, 1882).

Membranipora serrilamella Osburn, 1950. On blades of Macrocystis.

Reginella nitida Osburn, 1950. See Osburn (1950).

Celleporaria brunnea (Hincks, 1884).

Coleopora gigantea (Canu and Bassler, 1923).

Cryptosula pallasiana (Moll, 1803).

Eurystomella bilabiata (Hincks, 1884). Found only on the inner transect.

Hippodiplosia insculpta (Hincks, 1882). The most abundant bryozoan, encrusting red and brown algae.

Hippothoa sp.

Lagenipora spinulosa Osburn, 1952. See Osburn (1952).

Phidolopora pacifica (Robertson, 1908). Found normally on the vertical faces of the armor stones.

ENTOPROCTA

PEDICELLINIDAE

Barentsia gracilis (M. Sars, 1835).

ENCHINODERMATA

ENCHINOIDEA

Strongylocentrotus purpuratus (Stimpson, 1857).

Strongylocentrotus franciscanus (Agassiz, 1863). Found deep in the crevices of the armor stones along the outer transect.

Strongylocentrotus sp. Many specimens were too small to allow species identification.

ASTEROIDEA

Dermasterias imbricata (Grube, 1857). More common along the inner transect.

Henricia leviuscula (Stimpson, 1857).

Patiria miniata (Brandt, 1835). Ninety three percent of the population had the annelid Ophiodromus pugettensis in their ambulacral grooves. One specimen carried 73 individual worms.

Evasterias troschelli (Stimpson, 1862). A single specimen was excavated at the depth of 70 cm in the rubble along the inner transect.

Leptasterias hexactis (Stimpson, 1862).

Orthasterias koehleri (de Loriol, 1897).

Pisaster brevispinus (Stimpson, 1857).

Pisaster giganteus (Stimpson, 1857).

Pisaster ochraceus (Brandt, 1835).

Pycnopodia helianthoides (Brandt, 1835). Small specimens were always beneath the rubble. Large specimens were found mainly on the mud along both transects.

OPHIUROIDEA

Amphiodia occidentalis (Lyman, 1860). Found only in the mud on the outer transect.

Ophionereis eurybrachyplax Clark, 1911. Occurred between depths of -7 m to -13 m, only on the outer transect.

Ophioplocus esmarki Lyman, 1874.

Ophiopteris papillosa (Lyman, 1875).

Ophiothrix spiculata LeConte, 1851.

HOLOTHUROIDEA

Parastichopus californicus (Stimpson, 1857).

Parastichopus parvimensis (Clark, 1913). A single specimen was found on the undersides of an armor stone on the inner transect. See Brumbaugh (1980).

Cucumaria miniata Brandt, 1835. Common.

Cucumaria piperata (Stimpson, 1864).

Eupentacta quinquesemita (Selenka, 1867).

CHORDATA

ENTEROGONA

Aplidium californicum (Ritter and Forsyth, 1917).

Aplidium solidum (Ritter and forsyth, 1917).

Archidistoma diaphanes (Ritter and Forsyth, 1917).

Clavelina hunstmani Van Name, 1931. Common on the outer transect.

Cystodytes lobatus (Ritter, 1900).

Cystodytes sp.

Ascidia ceratodes (Huntsman, 1912).

PLEUROGONA

Boltenia villosa (Stimpson, 1864). Small specimens were found attached to the tubes of the terrebellid Eupolymnia crescentis on the mud along the outer transect. Large specimens (3 cm) were found on the vertical faces of the armor stones along the inner trahsect.

Cnemidocarpa finmarkiensis (Kiaer, 1893).

Halocynthia hilgendorfi igaboja Oka, 1906. Fairly common among the stones of the inner transect.

Pyura haustor (Stimpson, 1864). One specimen was excavated at a depth of 60 cm in the rubble.

Styela montereyensis (Dall, 1872).

Styela truncata Ritter, 1901. Found nestled among algal holdfast.

ALGAE

Identified using Abbott and Hollenberg (1976) or by Dr.
I.A. Abbott.

CHLOROPHYTA

Bryopsis corticulans Setchell, 1903.

Ulva expansa (Setchell) Setchell and Gardner, 1920.

Ulva lobata (Kutzing) Setchell and Gardner, 1920.

PHAEOPHYTA

Ralfsia pacifica Hollenberg, 1944.

Demareastia ligulata var. ligulata (Lightfoot), Lamouroux,
1813.

Macrocystis pyrifera (Linnaeus) C. Agardh, 1820.

Egregia menziesii (Turner) Areschoug, 1876.

Cystoseira osmundacea (Turner) C. Agardh, 1820.

RHODOPHYTA

Lithothamnium californicum Foslie, 1900.

Lithothamnium pacificum (Foslie) Foslie, 1906.

Lithothamnium sp.

Coralline officinalis var. chilensis (Decaisne) Kutzing
1858.

Bossiella californica (Decaisne) Silva, 1957.

Bossiella chiloensis (Decaisne) Johansen, 1971.

Bossiella orbigniana (Decaisne) Silva, 1957.

Endocladia muricata (Postels and Ruprecht) J. Agardh, 1847.

Grateloupia doryphora (Montagne) Howe, 1914.

Geldium pusillum (Stackhouse) LeJolis, 1863.

Prionitis filiformis Kylin, 1941.

Prionitis lanceolata (Harvey) Harvey, 1853.

Iridaea cordata (Turner) Bory, 1826.

Iridaea flaccida (Setchell and Gardner) Silva, 1957.

Iridaea lineare (Setchell and Gardner) Kylin, 1941.

Rhodoglossum californicum (J. Agardh) Abbott, 1971.

Rhodymenia californica Kylin, 1931.

Rhodymenia pacifica Kylin, 1931.

Botryocladia pseudodichotoma (Farlow) Kylin, 1931.

Gigartina corymbifera (Kutzing) J. Agardh, 1876.

Gigartina exasperata Harvey and Bailey, 1851.

Gigartina spinosa (Kutzing) Harvey, 1853.

Cryptopleura lobulifera (J Agardh) Kylin, 1924.

- Botryoglossum farlowianum (J. Agardh) De Toni, 1900.

APPENDIX D

LIST OF FISHES

Identified using Miller and Lea (1972).

Plainfin Midshipman, Porichthys notatus. A single specimen was observed at the base of the inner breakwater.

Northern Clingfish, Gobiesox maeandricus. Found when overturning rocks for quadrat sampling.

Cooper Rockfish, Sebastes caurinus. Common.

Whitebelly Rockfish, Sebastes vexillaris.

Treefish, Sebastes serriceps. Normally found residing in deep crevices in the armor stones.

China Rockfish, Sebastes nebulosus.

Gopher Rockfish, Sebastes carnatus.

Kelp Rockfish, Sebastes atrovirens. Common on the outer breakwater.

Black Rockfish, Sebastes melanops.

Blue Rockfish Sebastes mystinus. The most common rockfish seen, but very few large adults.

Olive Rockfish, Sebastes serranoides.

Painted Greenling, Oxlebius pictus.

Lingcod, Ophiodon elongatus. Common during their spawning months of November through January. On a single dive along the inner breakwater, 15 individuals were counted within a 20 m² area. The larger concentration along the inner breakwater was probably due to the fact that no sport diving is allowed on the harbor side of the breakwater.

Kelp Greenling, Hexagrammos decagrammus.

Rock Greenling, Hexagrammos superciliosus. Juveniles were common.

Cabazon, Scorpaenichthys marmoratus. All specimens seen were large adults, one was estimated to exceed five kg.

Longfin sculpin, Jordania zonope.

Red Irish Lord, Hemilepidotus hemilepidotus.

Coralline Sculpin, Artedius corallinus. Extremely common.

Smoothhead Sculpin, Artedius lateralis.

Tidepool Sculpin, Obigocottus maculosus. The most common sculpin seen.

Rosy Sculpin, Obigocottus rubellio.

Kelp Bass, Paralabrax clathratus. A small school exists on the inside of the breakwater. The largest individual was estimated to exceed 2.5 kg.

Opaleye, Girella nigricans. Several large specimens were seen among the armor stones along the inner breakwater.

Halfmoon, Medialuna californiensis. Seen along the inner breakwater.

Rubberlip Surfperch, Rhacochilus toxotes. Common.

Barred Surfperch, Amphistichus argenteus.

Calico Surfperch, Amphistichus koelzi.

Walleye Surfperch, Hyperprosopon argenteum.

Pile Surfperch, Darmalichthys vacca.

Wolf Eel, Amarrhichthys ocellatus. One large specimen was found in the crevices of the armor stones along the outer breakwater.

Giant Kelpfish, Heterostichus rostratus. A large specimen (40 cm) was observed guarding an egg mass in the Macrocystis.

Crevice Kelpfish, Gibbonsia montereyensis. Common throughout the breakwater.

Monkeyface Eel, Cebidichthys violaceus. Common in the crevices of the armor stones.

Black Prickleback, Xiphister atropurpureus. Common, hiding in the rubble.

Red Gunnel, Pholis schultzi.

Blackeye Goby, Coryphopterus nicholsii. Very common in the rubble.

California Halibut, Paralichthys californicus. Small individuals were seen on the mud flats around the outer breakwater.

Pacific Sanddab, Citharichthys sordidus. Common along the mud of the outer breakwater.

Common Mola, Mola mola. Two specimens were observed swimming along the outer breakwater during the month of August.

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